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Post Remedial Monitoring Plan

L.E. Carpenter & Company
Borough of Wharton, Morris County, New Jersey

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Section 1

Introduction

On behalf of L.E. Carpenter & Company (LEC), RMT, Inc. (RMT) is presenting this Post Remedial Monitoring Plan (PRMP) for the Borough of Wharton, Morris County, New Jersey, Superfund site (USEPA ID No. NJD002168748) as required following implementation of the source reduction remediation specified in the 2004 *Remedial Action Workplan (RAWP)*. The RAWP, including addendums resulting from the review and comment period (September and November 2004), was approved by New Jersey Department of Environmental Protection (NJDEP) and the United States Environmental Protection Agency (USEPA) on December 21, 2004. This PRMP also follows guidance and specifications presented in the 2005 *Monitored Natural Attenuation (MNA) (Monitoring Program Revision 2)* document dated January 13, 2005.

1.1 Remedial and Investigative Background

The initial environmental investigations at the site were performed in response to sampling activities performed by the NJDEP in 1980 and 1981. These activities resulted in LEC entering into an Administrative Consent Order (ACO) in 1982. The site was added to the National Priorities List (Superfund) in 1985. The 1982 ACO was superseded by an additional ACO in 1986, which required LEC to initiate a remedial investigation and a feasibility study (RI/FS).

In April 1994 NJDEP issued a Superfund record of decision (ROD) for the LEC site. The ROD summarized the results of the remedial investigation (RI), the baseline risk assessment, and outlined feasible remedial alternatives. A detailed summary of remedial investigation and remediation efforts conducted following issuance of the ROD is presented in the RAWP.

In 1997 RMT began site management and engineering services, four years after the ROD implementation had begun. At that time it had been discovered the remedial alternative for groundwater was not feasible, and only partial completion of the other ROD-mandated alternatives listed above had been implemented. No treatment system for groundwater had begun because a pilot test had shown the re-infiltration of treated groundwater as outlined in the ROD would not work due to the high clay content of most of the near surface soils, and because removal of immiscible product occurred at a much slower pace than originally anticipated and had not yet been completed. In addition, although some of the hot-spots had been excavated, soils contaminated with elevated levels of lead were determined to be much more extensive than previously thought.

RMT's initial efforts focused on enhancing the existing free product recovery system and ongoing site monitoring and reporting activities. However, it soon became clear the initial ROD was written based on only a partial understanding of the hydrogeology and nature and extent of the remaining contaminants of concern. RMT then performed detailed analyses of groundwater flow, free product recovery, and characterization and delineation of lead soils in order to address the remedial alternative deficiencies in the ROD. Much of our efforts focused on feasibility studies for removal of the extensive mass of immiscible light non-aqueous phase liquid (LNAPL).

Once an agreement had been reached regarding an acceptable approach that could replace the ROD-mandated cleanup alternatives, RMT prepared the comprehensive RAWP for Source Reduction. In summary, the RAWP outlined the following remedial activities:

- Lead and PCB soil excavation to residential levels, screening, and off-site disposal.
- Excavation, screening, and off-site disposal of hazardous process wastes existing in two on-site areas delineated in previous investigations.
- Excavation, screening, and reuse of delineated clean soils.
- Excavation of smear zone soils existing within the saturated zone through an amended slurry.

The source reduction work began on January 7, 2005, following the preconstruction meeting held at the LEC site on January 6, 2005. The source reduction work, which consisted of the excavation and off-site disposal of lead-contaminated soils and process wastes, and removal of the bulk of LNAPL free product and its smear zone, was completed by June 7, 2005. All site grading and backfilling activities were completed by June 30, 2005.

The RAWP also specified development of a PRMP for the purposes of monitoring post-remediation groundwater contamination and potential natural attenuation processes.

1.2 Site Description

The LEC site is located at 170 North Main St., Borough of Wharton, Morris County, New Jersey (Figure 1). The site comprises Block 301, Lot 1 and Block 703, Lot 30 on the tax map of the Borough of Wharton, and occupies 14.6 acres in a mixed-use industrial, commercial and residential area. The site is bordered to the south by the Rockaway River; by a vacant lot (Wharton Enterprises) to the southeast; and by a compressed gas facility (Air Products) to the northeast. The Air Products buildings have been removed, and the property is currently a vacant lot. A residential area borders the site to the northwest and the Washington Forge Pond borders the site to the west. A drainage ditch is located between the Air Products site and the LEC site. A pedestrian foot trail (rails-to-trails area), constructed along the former railroad

right-of-way, bisects the site from north to south. During active LEC operations, the site consisted of several buildings and structures, some of which were partially demolished during the early 1990's as part of site decommissioning activities. Figure 2 is a map of the general site plan that depicts individual buildings present or formerly present at the site, and pertinent site features. In addition, a photographic overview of the remediated site is presented as Figure 3.

The regional and local geology, in addition to the site's hydrologic conditions, is detailed in the RAWP) and other numerous reports referenced therein, and is summarized as follows:

Bedrock at the LEC site consists mainly of Precambrian age metamorphic and igneous rocks covered by variable thicknesses (between about 40 feet on the west side of the site to about 180 feet under the east part of the site) of unconsolidated glacial and alluvial sediments. Regionally, Wharton is located near the southernmost extent of the most recent Wisconsinan glaciation event, within a terminal moraine. A terminal moraine is composed of glacial till (a heterogeneous mixture of clay, silt, sand, and gravel) deposited directly from glacial ice at the terminus of the glacier, or various proportions of till and stratified drift. Two other deposit types that are relevant to the LEC site are Rockaway River outwash gravels and more recent post-glacial alluvium consisting of silt and fine sand with minor clay and pebble to cobble gravel. Near-surface soils at the LEC site range from anthropogenic fill covering Rockaway River outwash sand and gravel on approximately the western half of the site, and deposits that appear to range from finer-grained post-glacial alluvium and/or till along the eastern half of the area.

In the western portion of the site, the uppermost stratum of native soils is composed largely of sand and gravel outwash, overlain by a relatively thin layer of fill. In the eastern portion of the site, this outwash unit is overlain by relatively low-permeability silt and clay that occurs within the upper 5 to 10 feet. Historical borings and exploratory trenching identified a significant amount of sand and gravel in the upper alluvial unit. In addition, the upper alluvial unit is quite variable laterally, and includes areas of silty sand as well as silt and clay (especially on the eastern side of the site). The upper alluvial unit of silt, sand, and clay overlies deeper permeable units (up to 180 feet deep) composed of sand gravel outwash and stratified drift.

The shallow native sediments on the western portion of the site have a hydraulic conductivity of approximately 37 feet/day (Weston, 1992a). The hydraulic conductivity of the upper stratum of silt and clay alluvium that occurs in the eastern portion of the site has not been measured, but is likely on the order of 1 foot/day or less, based on geologic log descriptions. The horizontal hydraulic gradient varies across the site, but it averages approximately 0.0016 ft/ft, based on examination of equipotential maps. Assuming a typical effective porosity of 0.3 (Freeze and Cherry, 1979), the horizontal groundwater seepage velocity is approximately 73 ft/year in the shallow portion of the outwash sand.

Shallow groundwater flow is substantially affected by adjacent surface water bodies and site features (*i.e.*, Rockaway River, Washington Forge Pond and dam, drainage ditch and wetlands). Groundwater flow direction in the shallow aquifer east of the rail spur is generally towards the east. Washington Forge Pond acts as a constant head boundary that provides the driving head for both shallow and deep groundwater flow. As a result, areas of the site exhibit upward vertical gradients, while the drainage ditch acts as a discharge zone, as does the downstream portion of the Rockaway River. The portion of the Rockaway River south of and immediately adjacent to the site is often a losing reach, particularly in drought periods when the groundwater levels beneath the site are depressed a few feet and a gradient from the River into the site occurs (see flow arrows on Figure 4). As one moves downstream (east towards the wetland area) the River oscillates between losing and gaining and the flow regime is often difficult to define. Shallow groundwater flow is also effected by the presence of the drainage ditch. The drainage ditch acts as a local groundwater "sink", and shallow groundwater flow direction from a large portion of the site is controlled by the drainage ditch. The regional groundwater "sink" for this area is the Rockaway River, and it is this feature that causes the strong upward vertical gradients observed for all of the on-site well clusters. Historical water level data for this site confirms the predominant upward vertical gradients across the site.

With the completion of the 2005 Source Reduction remediation, localized changes in groundwater flow might be expected. Specifically, a cement-bentonite slurry was emplaced to prevent backflow of groundwater and free product during excavating, thus allowing removal of the bulk of an LNAPL free-product layer and its' associated smear zone. The smear zone was formed as a result of seasonal water table fluctuations and mass-displacement of the water table related to the volume of released free product liquids. Based on observations made during the remedial action and historical groundwater data, over the area of LNAPL source reduction excavation (see yellow shaded area on Figure 4), the average water table will occur within the emplaced and solidified cement-bentonite slurry. This PRMP takes this feature into account in terms of monitoring well design and vertical monitoring locations. As shown on Figure 5, screened intervals are designed to monitor vertical zones in relation to the top and bottom boundaries of the slurry monolith. These relationships are also detailed on Table 2, which summarizes the purpose for each well and well cluster. Shallow groundwater may become perched atop the slurry monolith, especially during rainy periods. In addition, while the potentiometric surface of the water table is expected to occur within the monolith, any well completed across that elevation within the monolith may not yield a sufficient volume of groundwater for sampling purposes. Despite these localized conditions related to the slurry monolith, we anticipate the hydraulic flow potential will remain the same in terms of flow from the remediated area to the river and ditch receptors, as shown by the approximated groundwater flow arrows on Figure 4.

This PRMP has been designed to account for these localized changes, and is adequate for determining local groundwater flow directions, especially as they relate to the principle receptors; the drainage ditch and the Rockaway River. In addition, the screened intervals outlined in detail on Table 2 will adequately monitor residual contaminants that may occur both within and below the slurry monolith.

Section 2

Site Monitoring System

2.1 Pre-Remedial Monitoring System

The pre-remedial monitoring system consisted of six surface water elevation monitoring points (SG-D1 thru SG-D3 and SG-R1 thru SG-R3), three surface water quality monitoring points (SW-5, SW-7, and SW-8), 28 EFR wells, 69 groundwater elevation monitoring points, and 32 groundwater quality monitoring wells located throughout the LEC main source reduction and MW-19/Hot Spot 1 areas. The pre-remedial monitoring system is shown on Figure 2, and pre-remedial monitoring well construction details including depth, screened interval, water level, etc. are described in Table 1.

Following implementation of the RAWP and completion of the various preconstruction activities (e.g., abandonment of existing wells to prepare for the source reduction excavations) the remaining components of the pre-remedial monitoring system include the following existing wells: MW-8, MW-9, MW-12R, MW-15S & I, MW-17S, MW-18S & I, MW-21, MW-25R, MW-26, and all MW-19/Hot Spot 1 area wells. MW-26 was damaged beyond repair during construction activities and requires proper abandonment during the installation of the new monitoring system. In addition to continued monitoring of the MW-19/Hot Spot 1 area, the remaining components of the pre-remedial monitoring system (as listed above) will be enhanced to optimize monitoring efficiency, and provide continuing data regarding the natural attenuation (NA) processes within the remediated L.E. Carpenter and Wharton Enterprise properties.

Groundwater monitoring at wells MW-8, MW-9, MW-12R, MW-15S & I, MW-17, MW-18S & I, MW-19-2, MW-19-8, MW-19-9D, MW-19-11, and MW-21 will consist of evaluating groundwater flow only (*i.e.*, the wells will be used for water level measurements only and not for sampling).

2.2 Historical Site Groundwater Quality Trends and Flow Patterns

Groundwater quality has been measured in site wells routinely since 1989. The historical groundwater quality data shows that certain organic constituents, primarily xylene and di-ethyl-hexyl-phthalate (DEHP) are detectable in some wells at levels above New Jersey groundwater quality cleanup criteria (N.J.A.C. 7:9-6). Some of these exceedences are derived from water quality samples taken from wells producing turbid water. LEC will redevelop the existing wells proposed herein as continued monitoring points in order to reduce the potential for questionable data quality derived from excessive turbidity. In addition, installation of

dedicated sampling systems and the continued application of low flow sampling techniques (specifically the evaluation and documentation of stabilization criteria as referenced in Table 7) for all water quality monitoring points specified herein will help to minimize the turbidity experienced during sampling.

2.3 Proposed Post Remedial Monitoring System

Details of the proposed sampling program, discussed below, are also tabulated in Tables 2 through 6.

2.3.1 Groundwater Monitoring Well Location and Design

A total of 13 new monitoring wells will be installed at specific locations, as shown on Figure 4, to serve the following general purposes (see detailed purposes on Table 2):

- monitor background groundwater quality;
- intercept and monitor the upper transition zone between the backfill material and the cement/bentonite slurry monolith;
- intercept and monitor the lower transition zone between the cement/bentonite slurry monolith and the existing soil material left in place post remediation;
- monitor the deeper aquifer under the cement/bentonite slurry monolith; and
- monitor the downgradient shallow zone of the aquifer (where historical data show dissolved phase constituents occur) to determine NA process characteristics and long-term effectiveness in reducing constituents of concern (COCs) below applicable groundwater cleanup criteria. These wells will be installed west (upgradient) of the existing groundwater monitoring wells MW-21 and MW-25R located in the Wharton Enterprise property.

These new groundwater monitoring wells will be sampled on a quarterly basis for both COC and NA parameters as outlined on Tables 3 and 4.

One additional well will be installed in the MW-19/Hot Spot 1 area. MW-19-12 will be placed on the north side of Ross St., northwest of MW-19-11 and east of MW-19-8. Data from the first three quarters of groundwater sampling in 2005 suggests this location will be directly downgradient from the leading edge of dissolved phase groundwater contamination. This additional monitoring well will be sampled on a quarterly basis and analyzed for COC and NA parameters.

2.3.2 Surface Water Monitoring Point Location and Design

A total of seven surface water points will be monitored along the Rockaway River and within the drainage ditch that separates the LEC and Air Products properties. Each location will be established by installing permanent markers (e.g. steel pipe or staff gauge) that will be surveyed with the rest of the monitoring network. Figure 4 shows the proposed locations of the surface water monitoring points and Table 2 details the purpose for each sampling location. Surface water samples will be collected from all seven monitoring points on a quarterly basis and submitted to Lancaster Laboratory for benzene, toluene, ethylbenzene, and xylenes (BTEX) and DEHP analysis and compared to applicable surface water quality criteria (N.J.A.C. 7:9B).

Section 3

Field Methods

3.1 Post Remedial Monitoring Network Installation

3.1.1 Monitoring Well Installation

Each boring will be supervised and the geology logged by an RMT field geologist. The monitoring wells will be advanced utilizing sonic drilling technology. A sonic drill rig operates by advancing an outer steel casing downhole, providing a relatively tight seal between the drill string and the formation being drilled. This minimizes the potential for drag-down of upper native soils and fill materials, as well as any associated potential contamination. At the same time, this drilling method will alleviate problems of adequate formation penetration experienced by other drilling methods in the bouldery material that occurs at this site, and maximizes the recovery of subsurface soils/fill for purposes of geologic logging. Monitoring well casing and screens will arrive at the site in the original factory packaging and remain in the packaging until the casing and screen materials are installed in the borehole. Groundwater monitoring wells will be constructed with 2-inch-diameter stainless steel screens with 0.01-inch slots, and 2-inch-diameter stainless steel riser pipe. All connections will be made utilizing flush threaded o-ring couplings. Filter pack material will be placed in the borehole annulus to 2 feet above the top of the screen (note: in some of the areas with historical low groundwater elevations, it may only be possible to place 6-inches to 1-foot of filter pack above the top of the screen). A bentonite seal will extend to 2 feet above the filter pack and the annulus will be pressure grouted with a cement/bentonite grout to within 2 feet of the ground surface. Each well will be completed with a concrete pad at grade, a 2 inch-diameter riser pipe, a steel outer casing, and an ID Label. Traffic protection bollards will be placed on three sides of the steel outer casing if placed in an area frequented by vehicular traffic.

3.1.2 Borehole Logging Methods

Continuous soil/fill samples will be collected at all new well locations where feasible given the subsurface conditions and drilling equipment used. Soil sample materials will then be logged by denoting pertinent information on a borehole log form. An example borehole log form is included in Appendix A. Information that will be collected and recorded on this form includes:

- Name of drilling contractor
- Boring location
- Date started / completed
- Geologists name
- Drilling method
- Borehole diameter
- Water level observations

A description of the number of sampling runs, length of sampling runs, and the percent recovery of each sampling run will be collected and recorded from each sampling run. A geologic description will be provided for each major material type to include the following data:

- Material name
- Unified Soil Classification System (USCS) classification
- Particle or grain size ranges
- Plasticity
- Color
- Odor or Photoionization Detector (PID) reading
- Moisture content
- Density or consistency
- Geologic origin, formation name, or stratigraphic unit

Materials collected from each boring will not be sampled or retained after the completion of the boring unless otherwise specified. Materials will be containerized in 55-gallon drums, staged in an appropriate on-site location, and properly disposed of at an approved off-site facility following characterization approval.

3.1.3 Well Development Methods

Monitoring wells will be developed to improve hydraulic communication between the groundwater monitoring well and the surrounding geologic formation. Groundwater will be surged and removed from each newly installed monitoring well via a whaler pump. During the development process specific conductance, pH, turbidity, and temperature will be monitored and development continued until these parameters are stabilized (Ref. Section 3.10 and Table 7).

3.1.4 Decontamination Procedures

All non-disposable equipment will be cleaned and decontaminated prior to usage, between well installation points during the field activities, and at the close of each days field activities. The subcontracted driller will decontaminate all subsurface drilling equipment following each well completion. An on-site decontamination area will be set-up to facilitate this process. Decontamination will be performed by washing equipment in a mixture of clean water and an environmental detergent such as Liquinox or Alconox®. The equipment will be scrubbed to remove all gross contamination using a plastic bristle brush. The equipment will then be clean water rinsed using a high-powered pressure washer. All decontamination waters, personal protective equipment (PPE) and cleaning materials (e.g., brushes) will be containerized in 55-gallon drums, staged in an appropriate on-site location, and properly disposed of at an approved off-site facility following characterization approval

3.1.5 Surface Water Monitoring Points

Each of the seven surface water monitoring locations will be established by installing permanent markers (e.g. steel pipe or staff gauge) that will be surveyed with the rest of the monitoring network. Figure 4 shows the proposed locations of the surface water monitoring points and Table 2 details the purpose for each sampling location.

3.1.6 Professional Surveying

After well completion, a New Jersey (NJ) licensed professional surveyor will locate each well to within one tenth of a foot (0.1) from the centerline of the inner well casing referencing North American Datum (NAD 83). In addition, the surveyor will shoot a reference elevation to the nearest one-hundredth of one-foot (0.01) at the ground surface, and at a notched point on the internal casing (not the outer protective casing) referencing National Geodetic Vertical Datum (NGVD). Due to the potential for changes in the elevation of monitoring wells over time due to factors such as frost heave, ground subsidence and alteration to the well, all active monitoring wells will be resurveyed every five years by a NJ licensed professional surveyor.

3.1.7 Investigation Derives Wastes (IDWs)

Investigation derived wastes (IDWs) include drill cuttings, well development water, decontamination water and PPE. This material will be disposed of based on the type and presence of contamination detected at the sampling point or decontamination process. Development water, and decontamination water collected during well installation activities will be containerized in 55-gallon drums, staged in an appropriate

on-site location pending characterization for appropriate management. Drill cuttings, spent personal protective equipment and other solid waste materials will be placed in 55-gallon drums, separate from the containerized liquids, and staged at an appropriate on-site waste collection point pending characterization and off-site disposal.

3.2 Field Sampling Protocol and Procedures

A standard field sampling protocol will be followed for all groundwater sampling conducted for the L.E. Carpenter, Wharton, NJ facility. This protocol is described in the following paragraphs. Sampling personnel will be familiar with procedures and requirements of the approved groundwater sampling and analysis program. The samplers will have a copy of the current approved sampling and analysis program requirements in their possession, readily available for reference during each groundwater-sampling event.

The groundwater sample collection activities will be performed in accordance with the procedures listed below in order to obtain representative groundwater samples, avoid potential sources of cross-contamination, and limit the potential for erroneous data.

3.2.1 Monitoring System Point Inspection

The condition of the program wells, surface water measuring and sampling points and surrounding areas will be inspected and the conditions documented during each quarterly sampling event prior to the collection of data. The following information will be noted in a field notebook or on the monitoring well inspection form (included in Appendix A):

- The ground surface condition around the well (vegetation, safety hazards, access hazards, etc.).
- Well security features (presence of lock, lock key number, protective bollards, paint, visibility devices, evidence of tampering, traffic hazards, etc.).
- Condition of the well surface completion, including surface protector, protector cover, inner casing cap or plug, and concrete pad.
- Evidence of potential contamination at the wellhead including staining or suspicious containers.

After static water levels have been taken the sampling team will measure and record the well total depth to ascertain whether the well bottom may have any accumulated sediment. This can be accomplished by noting the tactile sensation occurring as the probe contacts the well bottom cap. A heavily sedimented well will feel “soft” while a well clear of sediment will feel “hard”. The presence of bentonite or other mud may be

noted adhering to the probe after withdrawal from the well. In addition, a comparative decrease in total well depth between monitoring periods is also an indication of well sedimentation.

If any well is damaged, such that the water level cannot be measured and/or a sample cannot be collected, the well will be repaired or, if applicable, appropriately decommissioned and reinstalled, as outlined in this Plan. The condition of any damaged well and the proposed future action will be documented in the corresponding monitoring report.

3.2.2 Groundwater and Surface Water Elevation Measuring Methods

To determine the static water elevation (SWE), the static water level (SWL) will be measured prior to purging and sampling at each groundwater sampling location. All on-site static water level measurements will be obtained on the first day of the sampling event or within a 24-hour period except as described in the following section. The measurement will be obtained prior to purging the groundwater monitoring well for water quality sampling. As previously mentioned each well has (or will have if newly installed) a permanent reference point on the top of the well casing, designated top-of-casing (TOC), from which all water-level measurements will be taken. The reference point has been surveyed to the nearest 0.01 ft. and referenced to NGVD 88. All wells will be allowed to barometrically equilibrate prior to the collection of the SWL. This can be accomplished by ensuring the vent holes are not obstructed. If a vent hole does not exist for a particular well, then RMT will create a vent hole by removing the slip cap and drilling a very narrow hole (1/16th-inch) through the vent cap using a portable drill.

The measurement will be taken using an electronic water level meter capable of accuracy of ± 0.01 feet. The meter will be decontaminated prior to each measurement. Minimum contact of the tape and probe/sounder and the water in the well is required to decrease the potential for cross contamination. Disposable latex gloves will be used while determining the SWL.

Prior to taking the measurement, field personnel will verify the surveyed reference point on the TOC. The depth to water measurement for each well will always be obtained at this location. The probe will be slowly lowered into the well until the sounder beeps and/or the LED becomes illuminated. The measurement will be read from the tape to the nearest 0.01-foot increment and recorded in the field notes. This data represents the SWL as measured in feet below the TOC measuring point.

The static water elevation (SWE) will then be calculated using the following equation:

$$\text{SWE} = \text{TOC} - \text{SWL},$$

Where

SWE = static water elevation (ft),

TOC = top of casing elevation (ft), and

SWL = static water level, depth to water below TOC (ft).

3.2.3 Field Instrument Calibration

All field instrumentation will be calibrated before and after each use. Instruments and equipment used to gather, generate, or measure environmental data will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications.

Equipment to be used during the field sampling will be examined to confirm that it is in good operating condition. This includes checking the manufacturer's operating manual and the instructions for each instrument to ensure that maintenance requirements are being observed. Field notes from previous sampling trips will be reviewed so notations on prior equipment problems are not overlooked, and those necessary repairs to equipment have been completed. A spare pH electrode and a thermometer will be sent to sampling locations where pH and temperature measurements are required, including those locations where a specific conductivity probe/thermometer is required.

Field instruments will include a water level indicator and a multi-function flow through cell and meter such as the QED-MP 20 that has multiple sondes for specific conductivity, dissolved oxygen (DO), pH, redox potential (Eh), temperature and turbidity. In the event an internally calibrated field instrument fails to meet calibration/checkout procedures, it will be removed from service.

The equipment will be checked for any mechanical or electrical failures, weak batteries, and cracked or fouled electrodes before mobilizing for field activities. The equipment will also be checked post shipment to the site. Calibrations and repairs will be recorded in a bound notebook with the date and the name of the person making repairs/calibrations. The equipment will be calibrated before use and at least once for every half day of use. In the event that a multiple sonde meter is not available, single sonde meters such as those listed below will be used for field measurements.

pH

The pH measurements will be made using a flow-through cell (or equivalent). During use, the pH probe will be calibrated utilizing pH 4, pH 7 and pH 10

buffer solutions. The pH of each sample will be measured in the flow-through cell. The pH measurements will be recorded to the nearest 0.1 pH standard unit (SU).

Specific Conductance

The specific conductance probe will be calibrated to a stock calibration solution. The calibration must be within 10 percent of the calibration value of the solution. Specific conductance measurements will be made in the flow-through cell, and are automatically corrected by the instrument to 25°C. Measurements will be reported in micromhos per centimeter ($\mu\text{mhos/cm}$).

Temperature

Temperature will be measured to the nearest 0.2°C within the flow-through cell. Temperature measurements are utilized directly by the instrument to correct the specific conductance reading.

Turbidity

To assess monitoring well development and the representative nature of groundwater samples, the groundwater may be field-analyzed for turbidity using an in-field nephelometer. The meter will be calibrated before use according to procedures outlined in the operations manual. Measurements will be reported in nephelometric turbidity units (NTUs).

Dissolved Oxygen

The DO measurements will be made using a dissolved oxygen meter (or equivalent) present within the suite of instruments contained within the flow cell. Calibration consists of exposing the probe to a known oxygen concentration such as air at 100 percent relative humidity or water of known oxygen content, and then adjusting the calibration control so the display shows a reading that matches the O₂ concentration of the known sample. The instrument automatically compensates for temperature to an accuracy of ± 1 percent of the dissolved oxygen reading between 5°C and 45°C; and to an accuracy of ± 1.5 - 2 percent between 0°C and 5°C. Calibration of all instruments will occur in the field, under field temperature and humidity conditions. Calibration will be performed once per day, prior to the start of sample collection activities. Calibration results will be recorded on meter calibration forms included in Appendix A.

3.2.4 Low Flow Groundwater Sampling Methods

This section summarizes methods and techniques that will be used to collect representative groundwater samples utilizing low flow sampling techniques. Low flow sampling techniques differ from the traditional purge and sample techniques and have been shown to both reduce sampling time, IDW generation, and improve sample quality. These techniques are accepted and recommended by several state and federal agencies, including the USEPA. The low flow techniques described in this document are adapted and are in agreement with methods described in the NJDEP document entitled "Low Flow Purging and Sampling Guidance" (Appendix B) which, in turn, was developed in accordance with the USEPA document entitled "Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures" (EPA/540/S-95/504).

To consistently obtain a high quality groundwater monitoring data, site monitoring wells will be purged and sampled at flow rates no greater than 0.5 L/min (500 mL/min). Purging will be performed for the purpose of removing water from the sample tubing and monitor indicator parameters in a closed flow-through cell until their stability is reached. Sample stability values are presented in Table 7. The techniques described in this document were developed for use with a specific suite of sampling equipment and instrumentation. Alternative techniques can be used if other equipment is used at the site. The suite of equipment applicable to this set of procedures includes:

- Portable or dedicated bladder pump
- Inline water quality flow cell
- Water level meter with drawdown alarm
- Air compressor or bottled gas
- Pneumatic controller

Sample collection will proceed in the following stepwise manner:

- Measure static water level and leave water level meter in well
- Assemble, insert and connect pump
- Purge well until water quality parameters stabilize (Ref. Table 7)
- Collect sample after removing flow cell
- Label sample and place on ice
- Remove and decontaminate pump
- Close up well and move to the next sampling location

It is anticipated that dedicated bladder pumps will be installed in each of the water quality sampling wells following the first two quarterly sampling events. These pumps will not be removed before, during or after sampling activities. The use of dedicated pumps will improve sample quality by decreasing water column turbidity induced by the lowering of a portable pump, and increase the reproducibility and well specific data. Additionally, the use of dedicated pumps will decrease the chance that pumps or tubing could cause cross contamination between wells. Finally the use of dedicated pumps and tubing will reduce the long-term labor costs associated with quarterly sampling events.

3.2.5 Surface Water Sampling

This section summarizes the techniques that will be used to collect representative surface water samples. Upon arrival at the surface water body (ditch or river), the shorelines will be examined and documented with digital pictures showing the condition of the surface water body and adjacent shoreline at the time of sample collection. Although none are anticipated following the recently completed source reduction, any visual seeps into the surface water will be located and documented and their locations recorded on a sketch map. Surface water sampling will be performed in a downstream to upstream progression to prevent potential increases in solids concentrations in downstream samples. Sampling procedures are as follows.

1. Locate an area where the sample collection can be staged without disturbing the water or sediment in the surface water body. Since the contaminants of concern at this location may be concentrated in the ditch and/or river sediments, do not disturb the surface water bottom or shore area so as to introduce sediment into the sample.
2. Decontaminate all sampling equipment before taking the first sample and between sampling points. Whenever a sample is collected, record all field measurements and chemistry determinations on an appropriate form.
3. To collect a sample, lower the stainless steel pond sampler into the surface water body and fill with water. If necessary, clear any vegetation from the top of the water to obtain a sample as sediment free as possible. Fill sample bottles, rinse the inside of the bottle cap with sample water, and screw the cap onto the bottle tightly. Gently shake the bottle if a preservative (for example, HNO_3 , H_2SO_4 or HCl) has been added.
4. Immediately put the samples requiring refrigeration into an insulated cooler with ice. Put all other samples into a box and keep away from direct sunlight.

3.2.6 Collection of Field Parameters During Sampling

Drawdown during purging should be minimal and the water level in the well should stabilize before commencement of sampling. To insure drawdown remains minimal, a

drawdown meter will be inserted into the well prior to purging that is capable of sensing changes in water level during purging operations. At no time during the sampling or purging process will drawdown in the well exceed 0.5 feet. If drawdown exceeds this value, then the purge rate will be reduced until the steady-state drawdown is less than this value. The pumping rate will not be reduced using a flow constricting valve. The resulting pressure drop across the valve (also known as an "orifice effect") can alter sensitive samples, particularly volatile organic compounds (VOCs) by degassing. Alternatively, pumping rate will be reduced (if required) by adjusting the flow regulator on the pump.

Wells will be purged until at least three consecutive readings, spaced 3 minutes or more apart, are within the indicator parameter ranges outlined in Table 7.

Purge water rates and volumes will be recorded frequently (*i.e.*, every 3-5 minutes). The frequency for collecting field readings is contingent upon the actual flow rate at which the well is being purged and will decrease as purge rates decrease. Also, observations regarding odor, color, turbidity, *etc.* will be recorded. Field forms for these measurements are included in Appendix A.

Stable dissolved oxygen, specific conductance and turbidity readings are considered the most reliable parameters for indicating whether stagnant water has been replaced by formation water. Due to the difficulty often experienced in stabilizing turbidity, an independent turbidity meter separate from the flow cell will be used. Water will be sampled directly from the flow cell discharge for use in the turbidity meter.

A final set of water quality readings will be recorded on the sample collection form (and/or chain of custody).

3.2.7 Field Sample Filtration Methods

Field filtration will take place for any location specifying a field filtered sample. Typically filtration will only take place for samples collected for metals analyses. A filtered sample is also referred to as a "dissolved" sample, while an unfiltered sample may be referred to as a "total" sample. Filtration of a sample will take place after the water quality parameters have stabilized and other non-filtered samples have been collected. Collection of a filtered sample will be performed by momentarily shutting off the pump, removing the flow cell device (if used) from the sampling line coming from the pump and attaching an inline 0.45 μm filter by pushing the filter barbette into the sample tubing. A sample will be collected directly from the filter outfall after three filter volumes have passed through the filter. The 0.45 μm inline filter will be

constructed of inert materials. If a unidirectional filter is used, the filter will be installed so that water will flow in the designed direction only.

3.2.8 Water Quality Sample Collection

During sampling, primary objectives and considerations include minimizing sample disturbance, avoiding sample exposure to air and extraneous contamination, and preserving sample integrity throughout collection.

Sample labels will be prepared by writing the project name and number, the sample location, the type of analysis requested, the time and date, and the sampler's initials on the label prior to placement on to the sample bottle. Sample bottles will be filled with the sample following the application of the sample label. Bottle labels will be filled in with waterproof ink.

Sample parameter collection will progress in the following order:

1. Unfiltered samples for in-field water quality measurements (not necessary if down well or flow-through cell measurements are taken).
2. Volatile organic compounds (*e.g.*, VOCs, methane).
3. Non-filtered, non-preserved (*e.g.*, sulfate, semivolatile organic compounds (SVOCs) and non-volatiles, phosphorous).
4. Non-filtered, preserved (*e.g.*, nitrogen series [ammonia, nitrates, nitrites, etc.]).
5. Miscellaneous parameters.

Sulfate samples will be collected before sulfuric acid preserved samples (*e.g.*, nitrogen series). Nitrogen series samples will be collected before nitric acid preserved samples (*e.g.*, dissolved metals). This will prevent accidental contamination of a sample with a preservative intended for another sample (*e.g.*, sulfuric acid preservation contaminating an unpreserved sulfate sample).

Before opening and filling sample containers the sampling area will be checked for potential sources of extraneous contamination. The area around the well will be clean and contaminated equipment or materials (such as cuttings) will be kept away from the well. Samples will be protected from airborne contaminants such as engine exhaust, blowing dust and organic fumes (*e.g.*, gas cans) by sampling upwind of these contaminants or removing them before sampling. Gloves appropriate for the contaminants encountered will be utilized. New, clean gloves will be used every time a new well is sampled or if current gloves show evidence of contamination. Only disposable gloves will be used.

Sample containers will not be opened until it is time to fill them. Any required preservative will be added immediately after filling a sample container if it has not been pre-added to the container by the lab. Sample containers will be slightly overfilled so that a positive meniscus is formed before adding the cap to prevent the inclusion of any air bubble or headspace in the sample container. Sample containers will not be overfilled so that sample preservative is washed out. Sample containers will be inverted against a hard surface and tapped to check for air bubbles. If air bubbles are present, the sample will be discarded and a new sample collected in a new container. After satisfactory sample is collected, the sample container will be placed in a protective plastic bag. The bag will be sealed with tape and the sample container placed on ice in a clean sample cooler. Following these procedures will help minimize sample turbulence, agitation, volatilization, degassing, atmospheric exposure, biodegradation, and exposure to extraneous contamination and heating of samples.

3.2.9 Sample Containers, Preservation and Thermal Management Methods

After sample collection, the container will be dried using a paper towel, placed inside a shock protective sleeve (bubble wrap), and placed inside a new Ziploc bag to protect against moisture damage. Forty (40) mL VOC vial may be placed within a foam sleeve instead of bubble wrap. If more than one 40 mL VOC vial is collected as part of a single "sample", then these three vials may be packaged together.

Samples must be chilled from ambient temperature to below 4 degrees C after collection and during shipment to the laboratory. To insure that samples do not exceed this temperature, samples will remain in a sample cooler at all times up until removal at the analytical lab. The sample coolers must be filled with new ice regularly and meltwater must be removed. Due to the potential for sample cross contamination, only water ice will be used as a cooling media (e.g. no "blue ice" or gel ice packets will be used). All items placed in a sample cooler must be sealed within plastic bags to prevent water wetting. Under no circumstances will samples be placed directly in a sample cooler without protection from meltwater. Samples received at the analytical lab with unreadable labels due to water saturation, breakage, abrasion, or label soak-off will be discarded and the samples will be recollected.

3.2.10 Sample Container Labeling Protocol

All samples will be labeled with an adhesive label supplied by the analytical lab. The label will contain the name of the lab, the name and affiliation of the sampler, the sample time and date, the intended analyte, the project name, and the well (or sample point) name. Field filtered samples will be denoted as such on the sample label or by

adding the suffix "FF" to the sample name. Duplicate samples will be blind labeled to shield the sample identity from the analytical lab. The sample point from which the duplicate will be collected will be recorded in the field notebook and/or on the field information sheet included in Appendix A.

3.2.11 Sample Transportation and Handling

Samples will be packed in a clean or new insulated cooler as soon as possible after collection has been performed as described above. Field personnel will be aware of the holding time for specific parameters and will make arrangements to have the samples shipped or couriered to the analytical lab to meet these holding times. As standard practice, no samples will be held by RMT overnight for field activities lasting longer than one day. All samples should be shipped to the analytical lab on the same day they are collected. Sample transport will take place using a common ground courier or by direct delivery to the lab.

3.2.12 Decontamination Procedures

All non-disposable equipment will be cleaned and decontaminated prior to use, between sampling points during the field activities, and at the end of each quarterly monitoring event. If decontamination cannot be performed at the sampling point, equipment such as sampling pumps will be disassembled, and the disposable components (bladders, tubing and o-rings) will be removed and discarded. Decontamination will be performed by washing sampling equipment in three separate solutions. The first solution will be a mixture of clean water and an environmental detergent such as Liquinox or Alconox®. The equipment will be scrubbed to remove all gross contamination using a plastic bristle brush. The second solution will consist of a clean water rinse and the third solution will be final clean water rinse. Following decontamination, equipment will be stored in clean containers or aluminum foil for transport between sampling points. Dedicated equipment (such as dedicated bladder pumps) that normally remains within the well will not be decontaminated unless removed from the well for maintenance purposes.

3.2.13 Disposal of Groundwater and Surface Water Monitoring Wastes

Monitoring wastes include water generated from purging wells, decontamination water, disposable decontamination supplies, and PPE. This material will be disposed of based on the type and presence of contamination detected at the sampling point or decontamination process. Purge water and decontamination water collected during monitoring activities will be containerized in an on-site 500-gallon poly tank, staged at an appropriate on-site location. This tank will be pumped dry as needed, and the waste

liquids hauled off site for appropriate management once characterization is complete. Spent PPE and other solid waste materials will be placed in 55-gallon drums, and staged at an appropriate on-site waste collection point for characterization and off-site disposal.

3.2.14 Chain of Custody Protocol

Chain-of-custody documentation enables possession of a sample to be traced from sample collection through analysis and disposal. A sample is considered under custody if:

1. the item is in a person's possession;
2. the item is in that person's view after being in his or her possession;
3. the item was in that person's possession and then placed in a secured location; or
4. the item is in a designated and identified secure area.

A chain of custody protocol will be established to document control of the collected samples from collection point to delivery to the analytical lab. Samples will be under the custody of a designated person at all times. The control of custody will be documented on a chain of custody form supplied by the analytical lab. The chain of custody form will document the names, signatures and affiliations of personnel in custody of the samples, the dates and times custody was transferred.

The field technician performing sample collection activities will be responsible for sample custody in the field. The laboratory sample custodian and analysts will be responsible for custody of the sample at the laboratory.

A copy of the Chain-of-Custody will be placed in the project files and the original will accompany the samples to the laboratory. The identity of field duplicate samples will not be disclosed to the analytical laboratory. Sample analysis request forms will be prepared by Field Personnel and reviewed by the project coordinator, project manager or RMT Laboratory Coordinator. The analytical request forms will accompany samples, or precede delivery of samples, to the laboratory.

Shipping containers will be sealed and accompanied by the Chain-of-Custody record, with appropriate signatures. The transfer of custody is the responsibility of the Field Personnel and the laboratory staff. The procedures to be implemented are as follows:

- Place completed chain-of-custody forms in a plastic bag, seal the bag, and tape it to the inside cover of the shipping container.

- After the samples are iced, seal the coolers with strapping tape and custody seals (if applicable), add the date to the custody seals, and ship the coolers to analytical lab using an overnight delivery service.
- Identify common carriers or intermediate individuals on the chain-of-custody form, and retain copies of all bills-of-lading.
- When the samples are received in the laboratory, handle and process them in accordance with the procedures in laboratory standard operating procedures (SOPs), or specified analytical methods.

In the laboratory, a sample custodian will be assigned to receive the samples. Upon receipt of a sample, the custodian will inspect the condition of the samples, reconcile the sample(s) received against the Chain-of-Custody record, log in the sample(s) in the laboratory log book, and store the sample(s) in a secured sample storage room or cabinet maintained at an appropriate temperature until assigned to an analyst for analysis. Custody will be maintained until the sample is discarded.

When samples requiring preservation by either acid (except samples for VOC analysis) or base are received at the laboratory, the pH will be measured and documented. The Laboratory sample custodian will adjust the pH, if necessary, and the RMT Laboratory quality assurance/quality control (QA/QC) Coordinator will be promptly notified of the pH adjustment so that sample collection procedures can be reviewed to determine if a modification is necessary.

Discrepancies observed between the samples received, the information on the Chain-of-Custody record, and the sample analysis request sheet will be resolved before the sample is assigned for analysis. The RMT Laboratory QA/QC Coordinator will be informed of any such discrepancy as well as its resolution. Results of the inspection will be documented in the laboratory sample logbook. Discrepancies will be documented in the analytical case narrative, as appropriate.

3.2.15 Field Activity Record Keeping

Field activities will be documented in a field notebook, by the use of field forms, and through digital photography. Generally the field logbooks will be used to document general activities and tasks including the dates, times, locations and personnel involved in specific activities. The field logbook will also be used to document deviations from workplans, errors, and other unforeseen circumstances. Finally the field logbook will be used to document miscellaneous information or data that does not fall under the scope of one of the field forms. Field forms will be used to document specific field data

such as well construction details, well development details, instrument calibration water level elevations, water quality sampling parameters, and other routine data collection activities. Quarterly photo documentation will be used to document site wide and sample location specific conditions at the time of sampling.

Information pertinent to investigations and monitoring events will be recorded in field logbooks. Field logbooks will be bound with consecutively numbered pages. Each entry in the field logbook will be preceded by the time which the activity took place. At a minimum, the field logbook will record the time the field team arrived at the site and left the site, and the time major activities were initiated and ended. The field logbook will also record the time subcontractors arrived and left the site and major activities performed. All subcontractors' names and affiliations will be noted in the logbook. The field logbook will also be used to document phone and personal conversations of a business nature with clients, regulators and subcontractors that take place while on-site. The pages will be dated and signed by the person who is recording the information. Work sketches or phrases that are recorded but deemed incorrect will be marked through in such a way as to still be legible, yet obviously struck from the text. Mark-throughs will be initialed and dated by the person striking the item.

Persons leading a sampling team or performing a distinct task will be issued a field logbook by the RMT Field Coordinator. That person will maintain the logbook throughout the investigation/monitoring event. At the conclusion of the various phases of the investigation, the field books will be collected and reviewed by the Field Coordinator.

Field forms will be used to document specific data collection activities as described above. Field forms to be used as part of activities at the L.E. Carpenter, Wharton, New Jersey facility are included in Appendix A. These forms include:

1. Title page
2. General notes form
3. Borehole logging form
4. Well construction diagram
5. Water level measurement form
6. Low flow water quality parameter stabilization form
7. Water quality sample collection form
8. Field instrument summary form
9. Field instrument calibration forms

3.2.16 Collection of Field Quality Control (QC) Samples

Field QC samples will be collected to assess the quality of the analytical data and to evaluate sampling and analytical reproducibility (precision). Field QC samples will consist of duplicate samples, field blanks, and trip blanks. If dedicated equipment is used, the chance for cross-contamination is eliminated and field blanks will not be collected.

Duplicate Samples

Duplicate samples, prepared by splitting a single sample between two separate containers, will be used to evaluate sampling and analytical reproducibility (precision). These samples will be collected at a rate of one duplicate for every 10 environmental water samples; however, duplicate collection will not be less than one per sampling event. Duplicate samples are to be collected to provide a range of expected contamination concentrations in the field, and will be submitted as blind duplicates to the laboratory. By selecting duplicate samples from areas that are free from contamination and from areas that are suspected or known to have contamination, the QC performance can be reviewed. Blind duplicate sample locations must be identified in the field notes, but not on the sample labels or chain of custody forms.

Trip Blanks

Trip blanks will be analyzed to assess the possible cross-contamination of VOCs resulting from diffusion of ambient contaminants through septa during sample shipment, as well as from possible contamination during bottle preparation. Trip blank samples consist of two 40-mL vials that are filled with deionized water in the laboratory prior to going to the field. Trip blanks will accompany the VOC water sample bottles from the laboratory to the field and will be returned with the VOC samples to the laboratory. A separate trip blank will be included in every shipping container that includes water samples intended for VOC analysis. The trip blanks will be analyzed at a rate of one trip blank for each daily shipment of 10 samples or less that the laboratory receives. (If more than 10 water samples in a day are collected for VOC analysis, additional trip blanks, as needed, will be analyzed.)

Field Blanks

Field (equipment) blanks will be collected and analyzed to assess procedural errors in sampling and equipment decontamination. Field blanks will be

collected at a rate of at least 1 for every 10 environmental samples that are collected, and will be collected where equipment is decontaminated between multiple sample points and where samples may be subject to cross contamination. When dedicated or disposable sampling equipment is to be used (i.e., only one sampling point), and there is no likelihood of cross contamination, no field blanks will be collected.

Section 4

Analytical Methods, Data Quality Objectives (DQOs) and Quality Assurance/Quality Control (QA/QC)

Detailed descriptions of the analytical methods, data quality objectives (DQOs), and QA/QC procedures can be found in the September 2005 Revised Quality Assurance Project Plan (QAPP Version 2) included as Appendix C of this PRMP.

Section 5

Reporting

5.1 Sampling and Reporting Schedule

Field sampling activities will be performed within either the first or second month of each quarter. As required by 1986 ACO to both NJDEP and USEPA, a quarterly report will be sent to on or before the last day of the month following the reportable quarter (*i.e.*, 1Q05 = April 30, 2005). Deviations from this schedule, if necessary, will be approved in advance by the NJDEP.

5.2 Quarterly Report Content

Quarterly reports will include a narrative description of the site and facility and the overall objective of the monitoring program. The quarterly events will include a narrative description of the significant actions performed as part of the event. The quarterly report will contain a general site location map and a site features map that will show the location of each monitoring point, an outline of the remediated area(s), and other relevant features.

Results of the quarterly event will be presented as a narrative description of the general water flow characteristics, including horizontal flow direction and gradient, vertical gradient, and the overall facility groundwater levels. Water table elevations will be presented in tabular form showing the survey coordinates, measuring point elevation, depth to water, total well depth, well screened interval, and calculated water table elevation value for each monitoring point. Finally water table elevations will be contoured using a geostatistical package such as SURFER, or manually contoured, to produce a water table elevation contour map for the site. The water table contours will be generated using both groundwater elevation data and surface water elevation data. Field data sheets showing the raw depth to water measurement readings will be included as an appendix to the quarterly report.

Water quality sampling results will be presented in a narrative format, including a narrative description of any exceedences if observed or deviations from methods presented in this Plan. Water quality results will be presented in tabular form showing the compound name, measurement units, the numerical standard and standard reference, and historical analytical results for each monitoring point over time. The table will also show the analytical results for each sampling point in the appropriate number of significant digits to reflect the analytical precision reported by the lab. Values that equal or exceed the numerical standard will be highlighted or shaded for easy reference. This table will also show the results of quality assurance samples, such as duplicates, trip blanks, and field blanks.

In addition to the written quarterly report as described above, L.E. Carpenter will prepare and submit a HAZSITE electronic data diskette to the NJDEP.

Based on the results and conditions observed during quarterly monitoring events, the following information may also be included in the quarterly monitoring reports.

- Deviations from the approved monitoring protocol and justifications for each deviation
- Time series trend plots, showing the graphical trends in certain selected water quality parameters over time. Generally the parameters selected for portrayal in graphical form will be parameters that do not have significant quantities of non-detectable analytical results.
- A narrative description of the long-term water level and water quality trends present at the site. This narrative will present possible explanations for observed trends, if identified.
- The results of the trend analysis will be used in conjunction with other water quality monitoring results to determine if degradation of groundwater from the site has occurred.

5.3 Report Certification Requirements

Quarterly reports will be certified by the signature of the project manager, senior geologist, and project hydrogeologist for the entity performing the sampling and an authorized representative of the client in accordance with the technical requirements for site remediation (N.J.A.C. 7:26E-1.5).

5.4 Reporting Logistics

An original signed copy (including the electronic HAZSITE data disk), along with two additional copies, of all quarterly and annual reports will be sent hardcopy to the assigned NJDEP case manager upon completion. Three additional copies of all completed quarterly and annual reports will be sent hardcopy to the assigned USEPA case manager. The current NJDEP and USEPA case managers will be responsible for distribution of copies of this report to other members of the project team. The current NJDEP and USEPA case managers for this facility are:

**Mr. Anthony Cinque
Bureau of Federal Case Management
Division of Responsible Site Party Remediation
NJDEP
CN028
Trenton, NJ 08625**

**Mr. Stephen Cipot
United States Environmental Protection Agency (USEPA)
290 Broadway
Floor 19
New York, NY 10007**

NJDEP and the USEPA will notify L.E. Carpenter & Company, in writing, of any change of address, number of report copies requested, or routing requirements.

Tables

Table 1
Pre-Remedial Monitoring Plan Network
L.E. Carpenter and Company, Borough of Wharton, Morris County, New Jersey

WELL LOCATION	WELL TYPE	WELL INSTALLATION AND CONSTRUCTION INFORMATION ⁽⁷⁾										PROFESSIONAL SURVEY INFORMATION				ELEVATIONS (FT. MSL)		
		MANAGING	INSTALLATION	TOTAL WELL	WELL	SCREEN	SLOT	TOP OF	BOTTOM OF	SCREENED	AQUIFER	BASELINE LOCATION (feet) ⁽⁸⁾		GEODETIC LOCATION		GROUND	OUTER	INNER
		CONSULTANT	DATE	DEPTH (FT)	DIAMETER (IN)	MATERIAL	SIZE (IN)	SCREEN (FT)	SCREEN (FT)	INTERVAL (FT)	SYSTEM	(Y) North	(X) East	LATITUDE	LONGITUDE			
CW-1	Caisson Well	ROY F. WESTON	-	-	-	-	-	-	-	-	-	754247.22	471142.06	40° 54' 14.2"	74° 34' 34.7"	630.23	633.75	
CW-3	Caisson Well	ROY F. WESTON	-	-	-	-	-	-	-	-	-	754203.93	471309.9	40° 54' 13.8"	74° 34' 32.5"	628.03	632.70	
GEI-1I	Piezometer	ROY F. WESTON	April to October 1989	44.34	2.00	PVC	0.02	31.62	41.62	10.00	I	754767.14	471095.56	40° 54' 19.3"	74° 34' 35.3"	627.84	630.33	630.18
GEI-2I	Piezometer	ROY F. WESTON	April to October 1989	46.28	2.00	PVC	0.02	31.50	41.50	10.00	I	754573.99	470499.76	40° 54' 17.4"	74° 34' 43.1"	635.32	637.75	637.60
GEI-2S	Piezometer	ROY F. WESTON	April to October 1989	22.21	2.00	PVC	0.02	10.00	20.00	10.00	S	754566	470506.18	40° 54' 17.3"	74° 34' 43.0"	634.86	637.27	637.07
GEI-3I	Piezometer	ROY F. WESTON	April to October 1989	53.29	2.00	PVC	0.02	30.00	40.00	10.00	I	754311.79	470453.7	40° 54' 14.8"	74° 34' 43.7"	636.96	639.39	639.25
MW-1(R)	Monitoring Well	ROY F. WESTON	February 3, 1995	22.50	4.00	STEEL	0.01	7.00	22.50	15.50	S	754207.21	470825.97	40° 54' 13.8"	74° 34' 38.8"	635.19	635.18	634.87
MW-2(R)	Monitoring Well	ROY F. WESTON	January 30, 1995	13.00	2.00	PVC	0.01	2.00	12.00	10.00	S	754272.74	471267.56	40° 54' 14.4"	74° 34' 33.1"	628.46	631.68	631.54
MW-3	Monitoring Well	WEHRAN ENG.	May 15, 1980	27.00	2.00	STEEL	0.01	1.50	27.00	25.50	S	754227.41	471302.62	40° 54' 14.0"	74° 34' 32.6"	628.04	631.67	631.96
MW-4 ⁽³⁾	Monitoring Well	WEHRAN ENG.	May 20, 1980	27.00	2.00	STEEL	0.01	1.50	27.00	25.50	S	754070.52	471162.53	40° 54' 12.4"	74° 34' 34.4"	628.26	631.71	631.90
MW-6(R)	Monitoring Well	ROY F. WESTON	January 25, 1995	10.98	2.00	PVC	0.02	0.98	10.98	10.00	S	754210.83	471191.61	40° 54' 13.8"	74° 34' 34.1"	629.22	632.04	631.82
MW-8 ⁽⁵⁾	Monitoring Well	GROUNDWATER TECHNOLOGIES	1983	19.00	2.00	STEEL	0.02	0.00	19.00	19.00	S	754099.29	471251.06	40° 54' 12.7"	74° 34' 33.3"	627.39	629.96	628.19
MW-9 ⁽⁵⁾	Monitoring Well	GROUNDWATER TECHNOLOGIES	1983	20.50	2.00	STEEL	0.02	0.50	20.00	19.50	S	754075.94	471111.03	40° 54' 12.5"	74° 34' 35.1"	628.61	631.09	629.58
MW-11S	Monitoring Well	ROY F. WESTON	April to October 1989	14.73	4.00	STEEL	0.02	4.37	14.41	10.00	S	754226.73	471126.83	40° 54' 14.0"	74° 34' 34.9"	630.63	632.66	632.36
MW-11I(R)	Monitoring Well	RMT, INC.	February 20, 1998	52.00	2.00	STEEL	0.01	42.00	52.00	10.00	I	754237.94	471128.05	40° 54' 14.1"	74° 34' 34.9"	630.29	633.07	632.73
MW-11D(R) ⁽³⁾	Monitoring Well	RMT, INC.	February 20, 1998	157.00	2.00	STEEL	0.01	147.00	157.00	10.00	D	754244.62	471124.66	40° 54' 14.2"	74° 34' 34.9"	630.06	632.75	632.49
MW-12S(R)	Monitoring Well	ROY F. WESTON	May 7, 1996	14.45	4.00	PVC	0.02	2.45	14.45	12.00	S	754055.97	471042.34	40° 54' 12.3"	74° 34' 35.9"	631.57	634.26	633.73
MW-13S	Monitoring Well	ROY F. WESTON	April to October 1989	16.39	4.00	STEEL	0.02	5.37	15.14	10.00	S	754353.97	471370.04	40° 54' 15.3"	74° 34' 31.7"	627.74	630.80	630.63
MW-13S(R)	Monitoring Well	ROY F. WESTON	January 27, 1995	17.00	2.00	PVC	0.01	2.00	12.00	10.00	S	754333.07	471365.71	40° 54' 15.0"	74° 34' 31.8"	627.66	630.36	629.99
MW-13I	Monitoring Well	ROY F. WESTON	July 31, 1989	46.30	2.00	STEEL	0.02	35.22	45.26	10.00	I	754337.8	471360.31	40° 54' 15.1"	74° 34' 31.9"	627.76	630.28	630.06
MW-14S	Monitoring Well	ROY F. WESTON	April to October 1989	15.46	4.00	STEEL	0.02	3.42	13.46	10.00	S	754255.02	471423.66	40° 54' 14.3"	74° 34' 31.0"	625.18	628.03	627.81
MW-14I ⁽³⁾	Monitoring Well	ROY F. WESTON	April to October 1989	44.30	2.00	STEEL	0.02	33.22	43.26	10.00	I	754250.22	471409.52	40° 54' 14.2"	74° 34' 31.2"	625.33	627.72	627.63
MW-15S ⁽³⁾	Monitoring Well	ROY F. WESTON	April to October 1989	25.94	4.00	STEEL	0.02	9.37	19.41	10.00	S	754326.58	470891.83	40° 54' 15.0"	74° 34' 38.0"	634.23	636.43	636.17
MW-15I ⁽³⁾	Monitoring Well	ROY F. WESTON	July 17, 1989	43.92	2.00	STEEL	0.02	30.55	40.26	10.00	I	754325.8	470901.47	40° 54' 15.0"	74° 34' 37.9"	634.14	636.28	636.06
MW-16S	Monitoring Well	ROY F. WESTON	April to October 1989	23.90	4.00	STEEL	0.02	7.37	17.41	10.00	S	754424.11	470704.1	40° 54' 15.9"	74° 34' 40.4"	631.97	634.09	633.87
MW-16I	Monitoring Well	ROY F. WESTON	April to October 1989	46.53	2.00	STEEL	0.02	32.22	42.26	10.00	I	754435.1	470710.17	40° 54' 16.0"	74° 34' 40.3"	631.83	634.48	634.36
MW-17S ⁽³⁾	Monitoring Well	ROY F. WESTON	April to October 1989	15.04	4.00	STEEL	0.02	5.20	15.24	10.00	S	754109.68	470759.85	40° 54' 12.8"	74° 34' 39.7"	632.35	634.32	634.19
MW-18S	Monitoring Well	ROY F. WESTON	April to October 1989	15.04	2.00	STEEL	0.02	4.37	14.41	10.00	S	754677.95	471117.26	40° 54' 18.4"	74° 34' 35.0"	627.62	630.88	630.66
MW-18I	Monitoring Well	ROY F. WESTON	April to October 1989	44.69	2.00	STEEL	0.02	34.22	44.26	10.00	I	754675.11	471106.07	40° 54' 18.4"	74° 34' 35.2"	627.75	630.59	630.44
MW-19 ⁽⁹⁾	Monitoring Well	ROY F. WESTON	May 20, 1991	17.00	4.00	STEEL	0.02	7.00	17.00	10.00	S	754537.15	470454.45	40° 54' 17.1"	74° 34' 43.7"	636.22	636.23	635.90
MW-19-1 ⁽⁹⁾	Monitoring Well	RMT, INC.	February 17, 1998	17.00	4.00	STEEL	0.01	6.00	15.50	9.50	S	754534.52	470427.63	40° 54' 17.0"	74° 34' 44.0"	635.93	635.96	635.64
MW-19-2 ⁽⁹⁾	Monitoring Well	RMT, INC.	February 17, 1998	16.00	4.00	STEEL	0.01	6.00	16.00	10.00	S	754551.81	470429.56	40° 54' 17.2"	74° 34' 44.0"	636.46	636.50	636.30
MW-19-3 ⁽⁹⁾	Monitoring Well	RMT, INC.	February 18, 1998	16.00	4.00	STEEL	0.01	6.00	15.50	9.50	S	754539.4	470394.2	40° 54' 17.1"	74° 34' 44.5"	636.97	637.06	636.70
MW-19-4 ⁽⁹⁾	Monitoring Well	RMT, INC.	February 18, 1998	16.00	4.00	STEEL	0.01	6.00	15.50	9.50	S	754505.39	470432.08	40° 54' 16.7"	74° 34' 44.0"	635.69	635.76	635.43
MW-19-5 ⁽⁹⁾	Monitoring Well	RMT, INC.	February 18, 1998	16.00	2.00	PVC	0.01	6.00	15.50	9.50	S	754565.53	470470.75	40° 54' 17.3"	74° 34' 43.5"	635.93	635.93	635.56
MW-19-6 ⁽⁴⁾⁽⁹⁾	Monitoring Well	RMT, INC.	October 28, 1999	20.00	2.00	STEEL	0.02	10.00	20.00	10.00	S	754578.87	470443.1	40° 54' 17.5"	74° 34' 43.8"	636.17	636.16	635.82
MW-19-7 ⁽⁴⁾⁽⁹⁾	Monitoring Well	RMT, INC.	October 29, 1999	20.00	2.00	STEEL	0.02	10.00	20.00	10.00	S	754595.66	470501.7	40° 54' 17.6"	74° 34' 43.1"	635.31	635.36	635.00
MW-19-8 ⁽⁴⁾⁽⁹⁾	Monitoring Well	RMT, INC.	October 28, 1999	20.00	2.00	STEEL	0.02	11.00	20.00	9.00	S	754617.42	470493.65	40° 54' 17.8"	74° 34' 43.2"	635.82	635.82	635.36
MW-19-9D ⁽⁴⁾⁽⁹⁾	Monitoring Well	RMT, INC.	July 10, 2001	35.00	2.00	STEEL	0.02	25.00	35.00	10.00	S	754590	470442	40° 54' 17.9"	74° 34' 42.4"	636.39	636.41	636.10
MW-19-10 ⁽¹⁰⁾	Monitoring Well	RMT, INC.	May 17, 2004	20.00	2.00	STEEL	0.02	10.00	20.00	10.00	S	754625.75	470590.81	-	-	634.72	634.81	634.43
MW-19-11	Monitoring Well	RMT, INC.	November 30, 2004	17.00	2.00	STEEL	0.01	7.00	17.00	10.00	S	754617.45	470546.95	40° 54' 18.2"	74° 34' 41.0"	634.22	634.26	633.67
MW-20	Monitoring Well	ROY F. WESTON	May 21, 1991	14.00	4.00	STEEL	0.02	4.00	14.00	10.00	S	754550.52	470647.25	40° 54' 17.2"	74° 34' 41.2"	634.22	636.43	636.17
MW-21 ⁽³⁾	Monitoring Well	ROY F. WESTON	May 22, 1991	15.00	4.00	STEEL	0.02	5.00	15.00	10.00	S	754240.97	471645.78	40° 54' 14.1"	74° 34' 28.2"	624.57	628.49	628.20
MW-22(R) ⁽³⁾	Monitoring Well	ROY F. WESTON	July 22, 1997	7.50	2.00	STEEL	-	-	-	-	S	754200.52	471409.13	40° 54' 13.7"	74° 34' 31.2"	625.34	627.71	627.53
MW-23	Monitoring Well	ROY F. WESTON	January 6, 1992	6.00	2.00	STEEL	0.02	1.00	6.00	5.00	S	754413.43	471469.4	40° 54' 15.8"	74° 34' 30.5"	628.10	630.35	630.04
MW-25(R) ⁽³⁾	Monitoring Well	ROY F. WESTON	July 22, 1997	10.00	2.00	STEEL	-	-	-	-	S	754201.83	471518.21	40° 54' 13.7"	74° 34' 29.8"	624.65	626.77	626.62
MW-26	Monitoring Well	ROY F. WESTON	May 8, 1996	11.80	4.00	PVC	0.02	1.80	11.80	10.00	S	754401.17	471174.36	40° 54' 15.7"	74° 34' 34.3"	630.24	633.79	632.66
RW-1	Recovery Well	ROY F. WESTON	June 17, 1991	30.00	8.00	STEEL	0.02	5.00	30.00	25.00	S	754183.96	470802.1	40° 54' 13.6"	74° 34' 39.1"	634.59	637.21	636.78
RW-2	Recovery Well	ROY F. WESTON	June 22, 1991	30.00	8.00	STEEL	0.02	3.00	30.00	27.00	S	754245.98	471289.8	40° 54' 14.2"	74° 34' 32.8"	629.20	631.18	631.08
RW-3	Recovery Well	ROY F. WESTON	June 21, 1991	28.00	8.00	STEEL	0.02	3.00	28.00	25.00	S	754315.59	471206.84	40° 54' 14.9"	74° 34' 33.9"	629.29	631.55	631.39
SG-D1 ⁽¹⁾	Drainage Channel Staff Gauge	RMT, INC.	November-98	NA	NA	NA	NA	NA	NA	NA	NA	754428.57	471240.37	-	-	625.81	-	-
SG-D2 ⁽¹⁾	Drainage Channel Staff Gauge	RMT, INC.	November-98	NA	NA	NA	NA	NA	NA	NA	NA	754285.43	471361.24	-	-	626.26	-	-

Table 1
Pre-Remedial Monitoring Plan Network
L.E. Carpenter and Company, Borough of Wharton, Morris County, New Jersey

WELL LOCATION	WELL TYPE	WELL INSTALLATION AND CONSTRUCTION INFORMATION ⁽⁷⁾										PROFESSIONAL SURVEY INFORMATION				ELEVATIONS (FT. MSL)		
		MANAGING CONSULTANT	INSTALLATION DATE	TOTAL WELL DEPTH (FT)	WELL DIAMETER (IN)	SCREEN MATERIAL	SLOT SIZE (IN)	TOP OF SCREEN (FT)	BOTTOM OF SCREEN (FT)	SCREENED INTERVAL (FT)	AQUIFER SYSTEM	BASELINE LOCATION (feet) ⁽⁸⁾		GEODETIC LOCATION		GROUND	OUTER CASING	INNER WELL
												(Y) North	(X) East	LATITUDE	LONGITUDE			
SG-D3 ⁽¹⁾	Drainage Channel Staff Gauge	RMT, INC.	November-98	NA	NA	NA	NA	NA	NA	NA	NA	754381.47	471548.31	-	-	625.83	-	-
SG-R1 ⁽¹⁾	Rockaway River Staff Gauge	RMT, INC.	November-98	NA	NA	NA	NA	NA	NA	NA	NA	754313.99	470408.70	-	-	640.92	-	-
SG-R2 ⁽¹⁰⁾	Rockaway River Staff Gauge	RMT, INC.	May 17, 2004	NA	NA	NA	NA	NA	NA	NA	NA	754056.10	470946.46	-	-	628.65	-	-
SG-R3 ⁽¹⁾	Rockaway River Staff Gauge	RMT, INC.	November-98	NA	NA	NA	NA	NA	NA	NA	NA	754113.47	471426.67	-	-	626.78	-	-
WP-A1	Area A Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754220.52	470825.71	40° 54' 13.9"	74° 34' 38.8"	635.69	635.72	635.21
WP-A2	Area A Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754249.34	470813.05	40° 54' 14.2"	74° 34' 39.0"	636.71	639.02	638.59
WP-A3	Area A Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754195.42	470717.12	40° 54' 13.7"	74° 34' 40.3"	635.37	635.37	634.96
WP-A4	Area A Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754229.46	470855.24	40° 54' 14.0"	74° 34' 38.5"	635.03	635.06	634.50
WP-A5	Area A Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754266.54	470886.02	40° 54' 14.4"	74° 34' 38.1"	635.10		637.25
WP-A6	Area A Well Point	ROY F. WESTON	1993	13.00	2.00	PVC	-	3.00	13.00	10.00	S	754184.69	470888.45	40° 54' 13.6"	74° 34' 38.0"	634.35		636.68
WP-A7	Area A Well Point	ROY F. WESTON	1993	11.00	2.00	PVC	-	1.00	11.00	10.00	S	754196.44	470999.43	40° 54' 13.7"	74° 34' 36.6"	632.34		634.28
WP-A8	Area A Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754260.25	470998.97	40° 54' 14.3"	74° 34' 36.6"	634.10		636.96
WP-A9	Area A Well Point	ROY F. WESTON	1993	16.00	2.00	PVC	-	6.00	16.00	10.00	S	754184.12	470935.26	40° 54' 13.6"	74° 34' 37.4"	636.62		638.72
WP-B1	Area B Well Point	ROY F. WESTON	1993	11.00	2.00	PVC	-	1.00	11.00	10.00	S	754218.63	471068.54	40° 54' 13.9"	74° 34' 35.7"	631.25		633.05
WP-B2	Area B Well Point	ROY F. WESTON	1993	11.00	2.00	PVC	-	1.00	11.00	10.00	S	754282.8	471115.71	40° 54' 14.5"	74° 34' 35.1"	629.88	631.98	631.65
WP-B3	Area B Well Point	ROY F. WESTON	1993	11.00	2.00	PVC	-	1.00	11.00	10.00	S	754243.43	471088.51	40° 54' 14.2"	74° 34' 35.4"	631.11		632.73
WP-B4	Area B Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754275.31	471156.49	40° 54' 14.5"	74° 34' 34.5"	629.33		631.96
WP-B5	Area B Well Point	ROY F. WESTON	1993	11.00	2.00	PVC	-	1.00	11.00	10.00	S	754296.93	471181.49	40° 54' 14.7"	74° 34' 34.2"	629.43		631.51
WP-B6	Area B Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754171.56	471223.53	40° 54' 13.4"	74° 34' 33.7"	629.12		631.26
WP-B7	Area B Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754179.91	471330.82	40° 54' 13.5"	74° 34' 32.3"	627.02		628.89
WP-B10	Area B Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754319.10	471144.76	40° 54' 14.9"	74° 34' 34.7"	629.82	632.52	632.14
WP-C1	Area C Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754087.66	471038.32	40° 54' 12.6"	74° 34' 36.1"	632.21		632.91
WP-C2	Area C Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754075.97	471074.74	40° 54' 12.5"	74° 34' 35.6"	632.42		633.86
WP-C3	Area C Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754066.60	471009.58	40° 54' 12.4"	74° 34' 36.4"	630.40		632.04
WP-C4	Area C Well Point	ROY F. WESTON	1993	-	-	-	-	-	-	-	-	754108.93	471050.74	40° 54' 12.8"	74° 34' 35.9"	631.84		632.67

FOOTNOTES

- (1) Elevation measured at the top of a 3.33 ft. Staff gauge. Reference elevation (ground) shot at the top of the staff gauge. Water depth based on a visual observation of the water level on the Staff gauge.
- (2) Corrected water level elevations utilize an average specific gravity of 0.9363 (RMT, Inc. product sampling in October 1999 @ MW-1(R); EFR-11 & WP-A8)
- (3) Wells included in the quarterly sampling program. Depth to water recorded before purging
- (4) Wells installed during new RI efforts per NJDEP and EPA request to further delineate MW19/Hot Spot 1 Area
- (5) No boring log or well construction diagram available. Well specific information determined from Weston Geologic Cross Section
- (6) "-" in the Quarterly Measurement Information section of this database indicates that the presence of free product was NOT detected at any measurable thickness and therefore did not generate a product elevation, product thickness nor require water level elevation to be corrected
- (7) "-" in the Well Installation and Construction Information section indicates that well construction logs were not available for review
- (8) Horizontal Datum: New Jersey State Plane Coordinate System NAD 83. Vertical Datum: NGVD 29
- (9) All "19 series" wells were resurveyed August 8, 2001 at owners request. Wells MW19 through MW19-5 were converted to flush mount wells to allow for through traffic. Professional survey performed by James M. Stewart, Inc., Philadelphia, PA
- (10) MW-19-10 was installed as part of the MNA/PDB efforts. SG-R2 replaced SG-R2 installed in Nov. 1998. Professional survey performed by James M. Stewart, Inc., Philadelphia, PA
- (11) Air Product monitoring wells and staff gauges located in the ditch were not sampled during 2nd quarter 2004 because no current access agreement was in place at the time of sampling.

GENERAL NOTES

All WP series wells finished elevation is 2 feet above nominal grade. Total depth of well only accounts for subsurface structure
Wells MW-1A, MW5, MW-7, MW-10, MW-11I, MW-11D, MW-14D, MW-17D, MW-18D, MW-22, MW-24, MW-25, WP-B8, Wp-D1, PZ-6A, PZ-2A(R), PZ-2AS, RW-1 have been abandoned
Wells MW-11I(R), MW11-D(R), MW-1(R), MW-2(R), MW-6(R), MW-22(R), and MW-25(R) are replacement wells

LEGEND

S: Shallow Aquifer System
I: Intermediate Aquifer System
D: Deep Aquifer System
R: Replacement Well
NAS: Not Assessable
REM: Removed
-/-: Value of 0.00. Free Product not encountered at well

Table 2
Data Quality Objectives (DQOs) and Well Selection Criteria (Rev. 3)
L.E. Carpenter & Company - Post Remedial Monitoring Plan October 2005

Well	Area Specific DQOs and Well Selection Criteria
MW-19/HOTSPOT 1 AOC ⁽¹⁾	
MW-19	Continue to establish baseline for MNA analysis and determine dissolved concentrations of COC parameter concentrations within the area of residual vadose zone contamination that was left in place (remaining source area) following the initial tank and soil removal activities conducted by Weston.
MW-19-4	Establish "background" baseline for MNA analysis and determine COC parameter concentrations in the area upgradient from the MW-19/HS1 residual source area.
MW-19-5	Continue to establish baseline for MNA analysis and determine concentrations of COC parameters downgradient from residual source area.
MW-19-6	Continue to establish baseline for MNA analysis and determine dissolved concentrations of COC parameters at NW edge of groundwater contaminant zone. Data from this well will also be used to continue verification of the lateral extent of groundwater contamination.
MW-19-7	Continue to establish baseline for MNA analysis and determine concentrations of COC parameters downgradient from residual source area.
MW-19-12 [New]	Establish baseline for MNA analysis and determine concentrations of potential COC parameter concentrations at a point where data from new well MW-19-11 shows location to be downgradient from residual source area.
SOURCE REDUCTION AOC	
MW-27S	Establish "background" baseline for MNA and COC constituents in the area upgradient from the source reduction remediated area. Also provide data for lateral groundwater flow definition. The shallow well will intersect the water table.
MW-28S MW-28I	Establish groundwater lateral and vertical flow direction and gradients within the LNAPL source reduction remediated area, sample annually to determine concentrations of COC parameters in the center of the source reduction remediated area. The shallow and intermediate screens will straddle the upper and lower contacts of the cement/bentonite slurry monolith [Note: the shallow well may only contain small amounts of perched water because the slurry was emplaced from between 0.5 to 1 foot above the water table, which was relatively high at the time of excavation. Therefore, the "shallow" well in this case may intersect groundwater perched atop the monolith, but may not yield an adequate volume of water for sampling purposes because of the average water table elevation within the slurry monolith, as well as the monoliths low permeability].
MW-29S	Establish baseline for MNA analysis and determine concentrations of COC parameters north of the downgradient end of the source reduction area, near the drainage channel. The shallow well will be screened across the water table.
MW-30S MW-30I MW-30D	Establish baseline for MNA analysis and determine concentrations of COC parameters within the downgradient portion of the source reduction remediated area, at a location where pre-remediation groundwater flow data and observations of COC/sheen seeps show contaminants were influent to the Drainage Ditch. The shallow and intermediate screens will straddle the upper and lower contacts of the cement/bentonite slurry [Note: the shallow well may only contain small amounts of perched water because the slurry was emplaced from between 0.5 to 1 foot above the water table at the time of excavation. Therefore, the "shallow" well in this case may intersect groundwater perched atop the monolith, but may not yield an adequate volume of water for sampling purposes because of the average water table elevation within the slurry monolith, as well as the monoliths low permeability]. The deep well will monitor groundwater quality approximately ten feet below the base of the slurry monolith.
MW-31S	Establish baseline for MNA analysis and monitor progression of MNA and COC parameter concentrations in groundwater further downgradient from the source reduction area at a location where pre-remediation groundwater flow data show contaminants could be influent to the Drainage Ditch.

Table 2
Data Quality Objectives (DQOs) and Well Selection Criteria (Rev. 3)
L.E. Carpenter & Company - Post Remedial Monitoring Plan October 2005

	Also establish groundwater elevation data to develop a baseline for evaluating specific groundwater flow directions that apparently change in response to seasonal groundwater and river-level fluctuations. The shallow well will intersect the water table.
MW-32S	Establish baseline for MNA analysis and monitor progression of MNA and COC parameter concentrations in groundwater adjacent to the downgradient edge of the source reduction area.
MW-33S	Establish baseline for MNA analysis and monitor progression of MNA and COC parameter concentrations within shallow groundwater adjacent to the downgradient edge of the source reduction area.
MW-34S	Establish baseline for MNA analysis and monitor progression of MNA and COC parameter concentrations in shallow groundwater further downgradient from the source reduction area at a location where pre-remediation groundwater flow data show contaminants could be influent to the Rockaway River. Also establish groundwater elevation data to develop a baseline for evaluating specific groundwater flow directions that apparently change in response to seasonal groundwater and river-level fluctuations.
MW-35S	Establish baseline for MNA analysis and monitor progression of MNA and COC parameter concentrations in shallow groundwater further downgradient from the source reduction area at a location where pre-remediation groundwater flow data show contaminants could be influent to the Rockaway River. Also establish groundwater elevation data to develop a baseline for evaluating specific groundwater flow directions that apparently change in response to seasonal groundwater and river-level fluctuations.
MW-25	This existing well will help establish hydraulic control downgradient from the source reduction remediated area, and will be sampled annually to verify anticipated non-concentrations of COC parameters downgradient from of the source reduction area.
SW-D-1 SW-D-2 SW-D-3	Determine concentrations of potential COC parameters within the Drainage Ditch, adjacent to the downgradient portion of the excavated source reduction area. Based on pre-remediation groundwater flow patterns, SW-D-2 is located where shallow groundwater from the source reduction remediated area would likely be influent to the ditch, SW-D-1 is upgradient from the source reduction area, and SW-D-3 is further downstream in the ditch near the point where the drainage ditch changes direction to flow into the Rockaway River.
SW-R-1 SW-R-2	Determine concentrations of potential COC parameters within the Rockaway River, adjacent to the downgradient portion of the excavated source reduction area. Based on pre-remediation groundwater flow patterns, these samples are located where shallow groundwater from the source reduction remediated area would likely be influent to the river.
SW-R-3	Determine river level for on-site groundwater flow definition.
SW-R-4	Determine surface water level to assist on-site groundwater flow definition and determine "background" concentrations of potential COC parameters in the upgradient surface water - Washington Pond. Washington Pond formed from the damming of the Rockaway River upstream from the source reduction remediated area.

COCs = Contaminants of Concern: benzene, toluene, ethylbenzene, xylenes, and bis (2-ethyl hexyl) phthalate (DEHP)

AOC = Area of Concern

MNA = Monitored Natural Attenuation

Note(s):

1. MW-19/Hot Spot 1 Area of Concern (AOC) is located in the northwestern portion of the LEC site; at the intersection of N. Main Street and Ross Street. In lieu of abandoning the majority of the well network in preparation for the Source Reduction Remedial Project (Ref. RAWP Table 7), the wells that comprise the MW19/Hot Spot 1 AOC network were the ONLY sample locations from which groundwater quality and MNA parameters were collected during the source reduction remedial project (4Q04 through 3Q05) and while this PRMP was being prepared and approved by both NJDEP and USEPA.

Table 3
Natural Attenuation and Remedial Design Analytical Methods (Rev. 3)
L.E. Carpenter & Company - Post Remedial Monitoring Plan October 2005

FIELD PARAMETERS	METHOD/EQUIPMENT	FREQUENCY
Dissolved oxygen (DO)	360.1 ⁽²⁾ /Probe/Hach Kit	Quarterly
Redox potential (Eh)	⁽⁴⁾ Redox electrode	Quarterly
pH	150.1 ⁽²⁾ /pH electrode	Quarterly
Temperature	From conductivity probe	Quarterly
Turbidity	Turbidimeter	Quarterly
Specific Conductance	120.1 ⁽²⁾ /Electrical conductivity meter	Quarterly
Ferrous iron	Hach kit; Method 8146	Quarterly
Carbon Dioxide (CO ₂)	Hach kit	Quarterly
Alkalinity (total)	Hach kit	Quarterly
Depth to water ⁽⁵⁾	Electric tape/Water Level Indicator	Quarterly
LABORATORY PARAMETERS	METHOD	FREQUENCY
Benzene	602 ⁽¹⁾	Quarterly
Toluene	602 ⁽¹⁾	Quarterly
Ethylbenzene	602 ⁽¹⁾	Quarterly
Xylenes	602 ⁽¹⁾	Quarterly
DEHP	625 ⁽¹⁾	Quarterly
Ammonia Nitrogen (N)	350.3 ⁽²⁾	Quarterly
Nitrate Nitrogen (N)	353.2 or 4110B ⁽²⁾⁽⁴⁾	Quarterly
Sulfate	375.4 or 4110B ⁽²⁾⁽⁴⁾	Quarterly
Heterotrophic Plate Count	9215B ⁽⁴⁾	Quarterly
Methane	3810 ⁽³⁾	Quarterly
Total Suspended Solids (TSS)	160.2 ⁽¹⁾	Quarterly
Total Dissolved Solids(TDS)	160.1 ⁽¹⁾	Quarterly
Phosphorus (total)	365.2 ⁽²⁾	Quarterly
Lead (dissolved)	6010B ⁽³⁾	Quarterly

Notes:

- ⁽¹⁾ Federal Register 40 CFR Part 136, Vol. 49, No. 209, Test Parameters for the Analysis of Pollutants.
- ⁽²⁾ USEPA 300/4-79-020 Methods for Chemical Analysis of Water and Waste.
- ⁽³⁾ SW-846, Test Methods for Evaluating Solid Waste, Physical and Chemical Methods, U.S. EPA, 3rd Edition, 1986.
- ⁽⁴⁾ Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998.
- ⁽⁵⁾ All wells listed on Table 1 will be measured before sampling begins.

Table 4
Field and Laboratory Analyte List (Rev. 3)
L.E. Carpenter & Company - Post Remedial Monitoring Plan October 2005

FIELD METHODOLOGIES		ANALYTES	
Purge Stability using a micro purge cell, probe and electrodes		DO, Eh, pH, Temperature, Turbidity, Specific Conductance	
Natural Attenuation criteria using a Hach field kit		Ferrous Iron, CO ₂ , Alkalinity	
LABORATORY METHODOLOGIES		ANALYTES	
Contaminants of Concern (COC)	Organics	BTEX	
		DEHP	
Natural Attenuation Criteria	Anions	Sulfate, Nitrate-N	
	Cations	Ammonia-N, Phosphorus (total), Lead (dissolved)	
	Other	Heterotropic Plate Count, TSS, TDS	
	Breakdown gases	Methane	

Table 5
Water Sample Containers, Preservatives, and Holding Times (Rev. 3)
L.E. Carpenter & Company - Post Remedial Monitoring Plan October 2005

PARAMETER	CONTAINER(S)	MINIMUM SAMPLE VOLUME	FIELD PRESERVATION METHOD	HOLDING TIME ⁽¹⁾
Volatile organics (<i>i.e.</i> , BTEX)	3 x 40 mL glass VOA vials with Teflon [®] (2) septum	1 x 40 mL VOA vial	Cool to 4°C, add HCl to pH < 2; protect from light	14 days (sample should remain on-site less than 24 hours)
Semivolatile organics (<i>i.e.</i> , DEHP)	1 x 1,000 mL amber bottle ⁽⁴⁾	1,000 mL	Cool to 4°C	7 days to extraction 40 days from extraction to analysis
Methane	2 x 40 mL VOA vials with Teflon [®] septum ⁽²⁾	1 x 40 mL VOA vial	Cool to 4°C; protect from light; may be preserved with HCl to pH < 2	7 days if unpreserved 14 days if preserved
Phosphorus (total)	Use an aliquot from the alkalinity bottle	100 mL	Cool to 4°C	28 days
Lead (dissolved)	1 x 500 mL high-density polyethylene bottle	500 mL	Cool to 4°C, add HNO ₃ to pH < 2	6 months
Sulfate	Use an aliquot from the alkalinity bottle	100 mL	Cool to 4°C	28 days
Ammonia-N	1 x 1000 mL high-density polyethylene bottle ⁽³⁾	100 mL	Cool to 4°C, add H ₂ SO ₄ to pH < 2	28 days
Nitrate-N	1 x 250 mL high-density polyethylene bottle ⁽³⁾	100 mL	Cool to 4°C, add H ₂ SO ₄ to pH < 2	28 days
Temperature, Eh, pH, Specific Conductivity, DO, Ferrous Iron, Turbidity, alkalinity, CO ₂	--	--	--	Immediately after sample collected
Heterotrophic Plate Count	120 mL sterile plastic	10 mL	Cool to 4°C, add Na ₂ S ₂ O ₃	24-hours
TSS	250 mL G/P	250 ml	Cool to 4°C	7 days
TDS	250 mL G/P	250 ml	Cool to 4°C	7 days

NOTES

(1) Starting from time of sample collection.

(2) Collect three extra containers for Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples.

(3) Collect one extra container for sample spike and duplicate analyses.

(4) Collect two extra containers for MS/MSD samples.

(5) QA/QC Sampling: 1 blind duplicate (all analytes); 1 atmospheric blank (all analytes); Trip Blank (BTEX only) @ 1 per cooler (approx 4 TBs/event); Rinsate Blank (all analytes);

Table 6
Natural Attenuation and Remedial Design Analytical Reporting Limits (Rev. 3)
L.E. Carpenter & Company - Post Remedial Monitoring Plan October 2005

Analyte	Reporting Limit
Ammonia-N	0.10 mg/L
Nitrate-N	0.1 mg/L
Phosphorus (total)	0.03 mg/L
Lead (dissolved)	0.0084 mg/L
Sulfate	5 mg/L
Methane	5 µg/L
Benzene	0.25 µg/L
Toluene	0.25 µg/L
Ethylbenzene	0.25 µg/L
Xylenes (total)	0.25 µg/L
DEHP	0.5 µg/L
Total Suspended Solids (TSS)	10 mg/L
Total Dissolved Solids(TDS)	20 mg/L
Heterotropic Plate Count	1 cfu/mL

NOTES:

cfu/mL: Colony forming units/milliliter

mg/L: Milligrams per liter

µg/L: Micrograms per liter

Table 7
Stabilization Criteria for Low-Flow Groundwater Sampling Field Parameters (Rev. 3) L.E.
Carpenter & Company - Post Remedial Monitoring Plan October 2005

Parameter	Stabilization Criteria
Dissolved Oxygen	± 0.3 mg/L
Specific Conductance	± 5.0 μ mhos/cm for values < 1000 μ mhos/cm ± 20.0 μ mhos/cm for values > 1000 μ mhos/cm
pH	± 0.1 pH units
Temperature	$\pm 0.5^{\circ}\text{C}$ or 5%
Turbidity	$\pm 10\%$ NTU or below 10 NTU

Figures

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No xref's Attached

Plot Time:
Attached Xrefs:

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Thursday, October 13, 2005

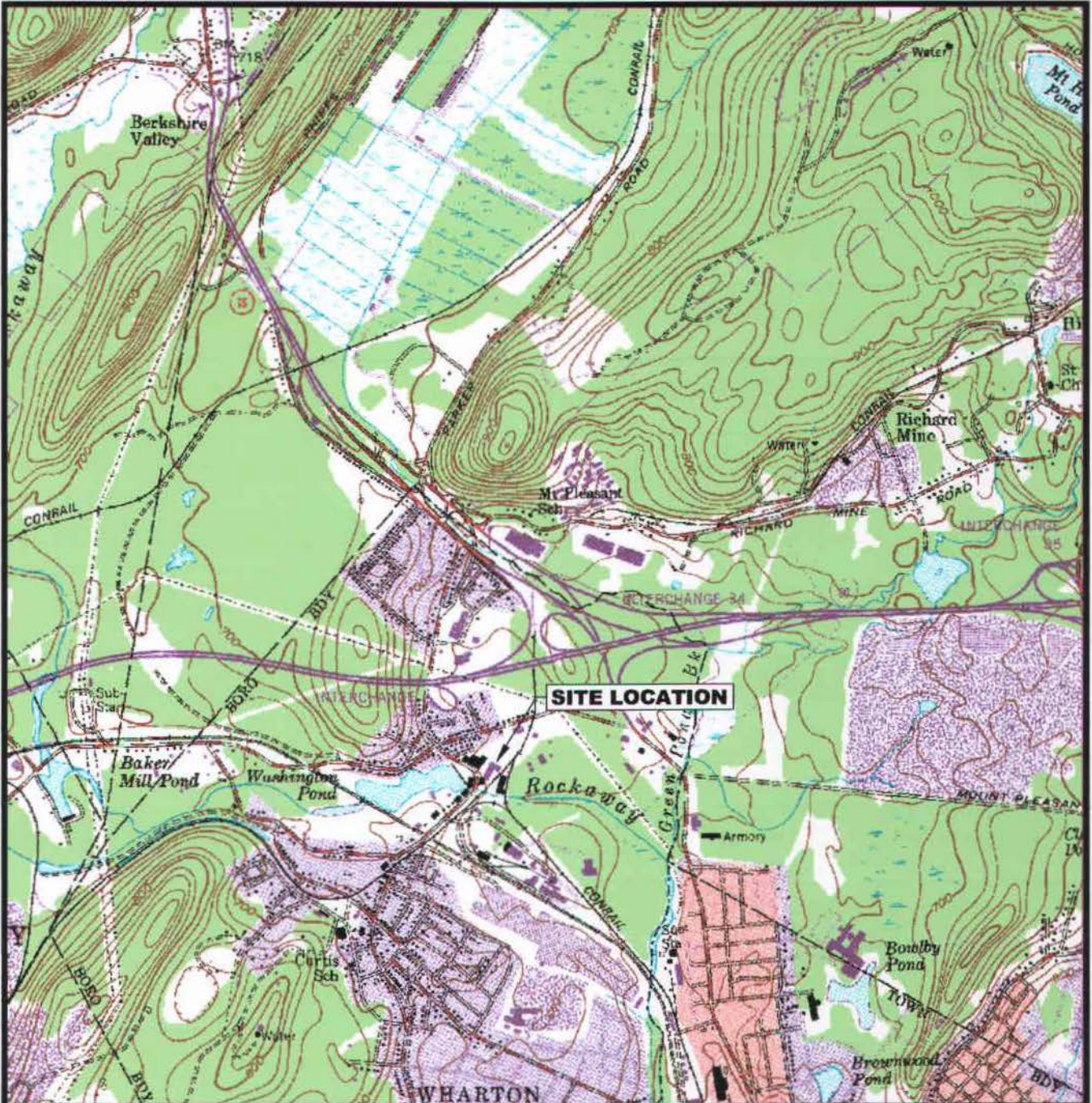
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Operator Name:
Scale:

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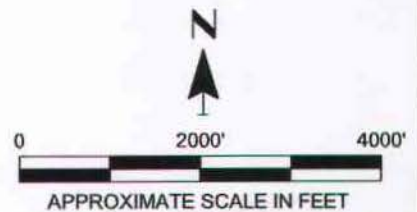
NEW JERSEY



SOURCE

BASE MAP DEVELOPED FROM THE DOVER, NEW JERSEY 7.5 MINUTE U.S.G.S. TOPOGRAPHIC QUADRANGLE MAP, DATED 1954, PHOTOREVISED 1981.

QUADRANGLE LOCATION



RMT INC.
®

**LE CARPENTER
WHARTON, NEW JERSEY**

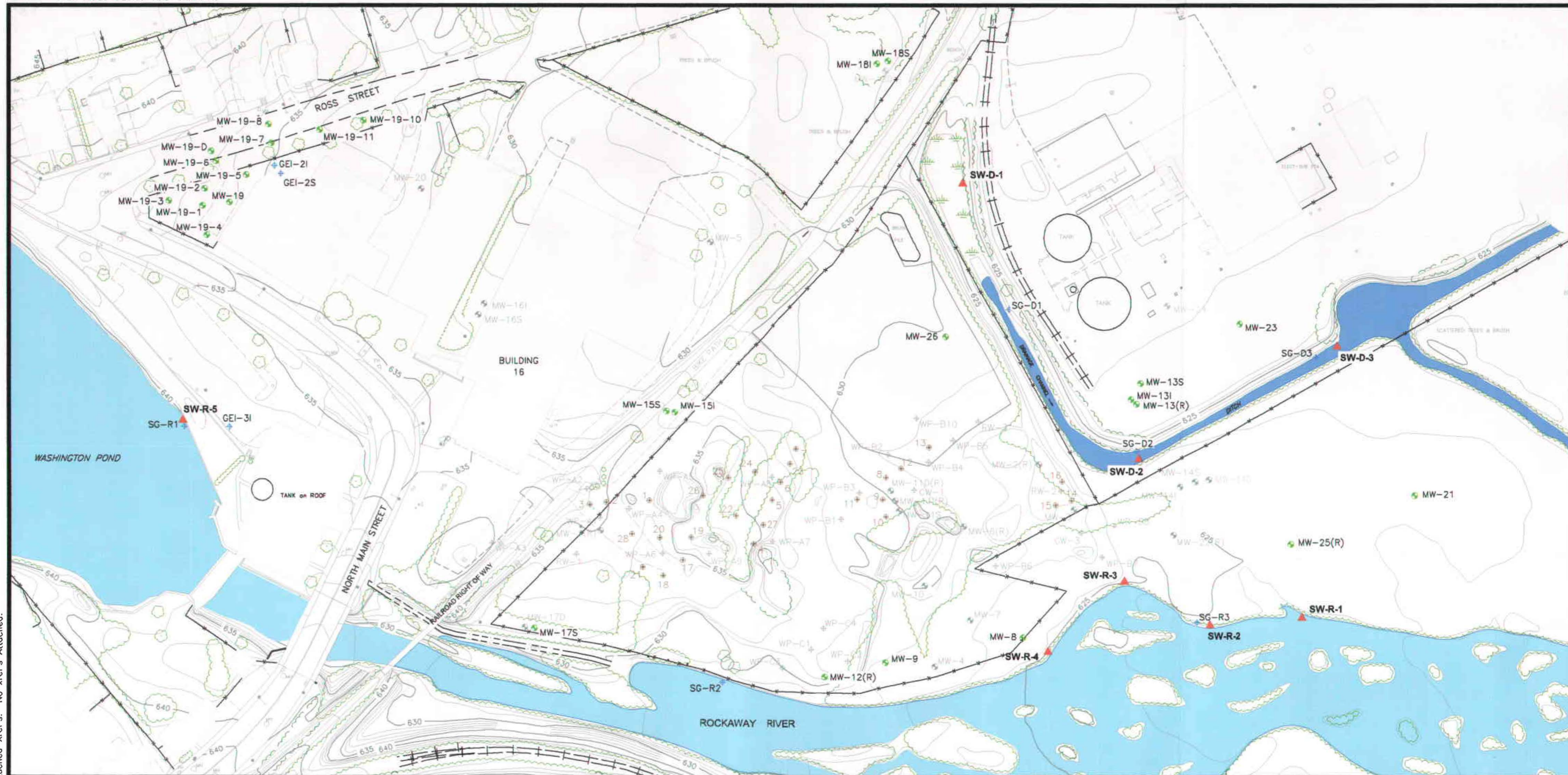
SITE LOCATION MAP

DRAWN BY:	SJL
APPROVED BY:	JO
PROJECT NUMBER:	6527.17
FILE NUMBER:	6527.17.01.DWG
DATE:	OCTOBER 2005

FIGURE 1

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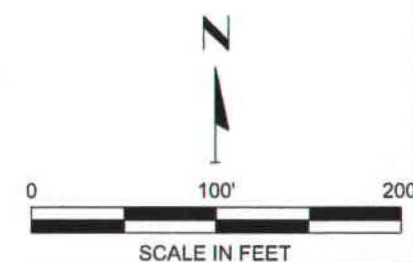


LEGEND

- | | | | |
|-------|--|--------|---|
| --- | PROPERTY LINE | WP-B7 | WELL POINTS |
| --- | FENCE | SG-R1 | RIVER POINT |
| MW-21 | MONITORING WELL | SG-D1 | DRAINAGE CHANNEL POINT |
| MW-24 | ABANDONED MONITORING WELL | GEI-21 | PIEZOMETERS |
| 13 | ABANDONED ENHANCED FLUID RECOVERY WELL | SW-D-1 | SURFACE WATER SAMPLING LOCATIONS (D = DITCH; R = RIVER) |
| RW-2 | ABANDONED RECOVERY WELL | | |
| CW-3 | ABANDONED CAISSON WELLS | | |

NOTES

1. BASE MAP DEVELOPED FROM TOPOGRAPHIC SURVEY PROVIDED BY JAMES M. STEWART, INC. LAND SURVEYORS, DRAWING NO 2793-03.DWG, DATED 02-14-02.



LE. CARPENTER
 WHARTON, NEW JERSEY

SITE PLAN WITH 3Q05 SAMPLE LOCATIONS



DRAWN BY:	SJL	PROJECT NUMBER:	6527.17
CHECKED BY:	JJD	FILE NUMBER:	6527.17.02.DWG
APPROVED BY:	NC	DATE:	OCTOBER 2005



1143 HIGHLAND DRIVE, SUITE B
 ANN ARBOR, MI. 48108-2237
 PHONE: 734-971-7080
 FAX: 734-971-9022





Photographic Log

Client Name: L.E. Carpenter & Company		Site Location: Borough of Wharton, Morris County, New Jersey	Project No.: 6527.17
Photo No. 1	Date 6/24/05		
Description Looking north - northeast down the Rails-to-Trails.			
Photo No. 2	Date 6/24/05		
Description Looking northeast out over the L.E. Carpenter site.			



Photographic Log

Client Name:		Site Location:	Project No.:
L.E. Carpenter & Company		Borough of Wharton, Morris County, New Jersey	6527.17
Photo No.	Date		
3	6/24/05		
Description			
Looking east out over the south side of the L.E. Carpenter site.			
Photo No.	Date		
4	6/24/05		
Description			
Looking east out over the south side of the L.E. Carpenter site along the Rockaway River.			



Photographic Log

Client Name:		Site Location:	Project No.:
L.E. Carpenter & Company		Borough of Wharton, Morris County, New Jersey	6527.17
Photo No.	Date		
5	6/24/05		
Description Looking up towards the Rails-to-Trails (west). Ground has been covered with hydroseed (green areas).			
Photo No.	Date		
6	6/24/05		
Description Looking east into the remediated and graded wetland area. Ground has been covered with hydroseed west of wetland area and free seeded with wetland specific seed mix east of hydroseeded area.			



Photographic Log







Client Name:		Site Location:	Project No.:
L.E. Carpenter & Company		Borough of Wharton, Morris County, New Jersey	6527.17
Photo No.	Date		
7	6/24/05		
Description			
Final grade up to the snow and silt fencing along the drainage ditch. Looking north.			

Photo No.	Date		
8	6/24/05		
Description			
The drainage ditch looking upstream from the curve/SW-D-2. Looking north-northwest.			





Photographic Log

Client Name:		Site Location:	Project No.:
L.E. Carpenter & Company		Borough of Wharton, Morris County, New Jersey	6527.17
Photo No.	Date		
9	6/24/05		
Description			
Close-up of the snow and silt fences along the east end of the PA area. A white boom can be seen in the background along the Rockaway River at the area of surficial sheen. Looking southeast. Absorbent booms and sweeps have since been removed.			
Photo No.	Date		
10	6/24/05		
Description			
View of the L.E. Carpenter site final grade from the remediated wetland area. Looking west.			

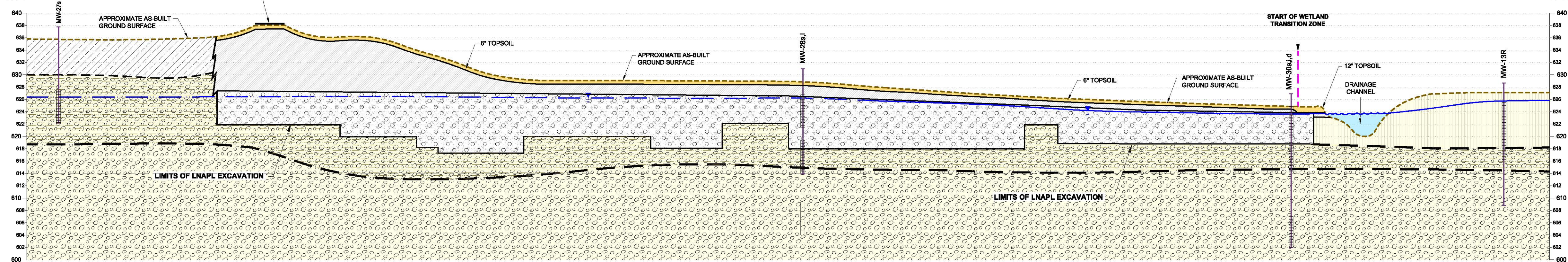


Photographic Log

Client Name:		Site Location:	Project No.:
L.E. Carpenter & Company		Borough of Wharton, Morris County, New Jersey	6527.17
Photo No.	Date		
11	6/24/05		
Description South side of the L.E. Carpenter site looking east, along the Rockaway River at AEC A-2.			
Photo No.	Date		
12	6/24/05		
Description South side of the L.E. Carpenter site looking west, along the Rockaway River at AEC A-2.			

West
A

East
A'

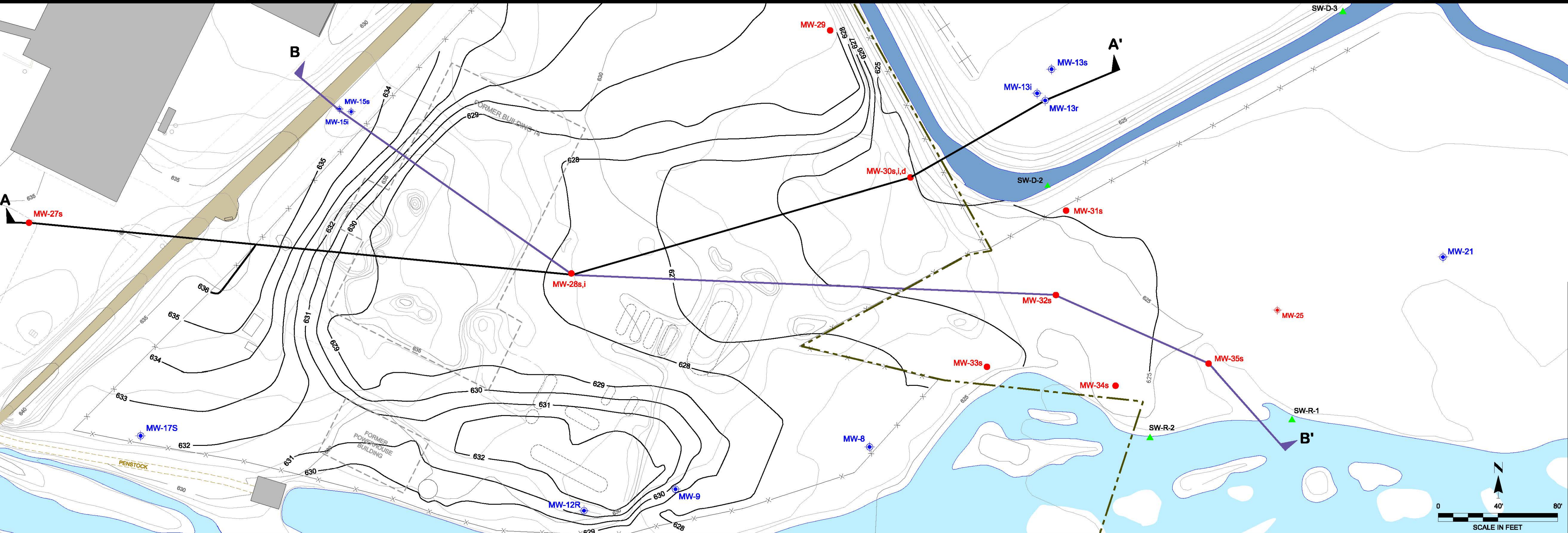
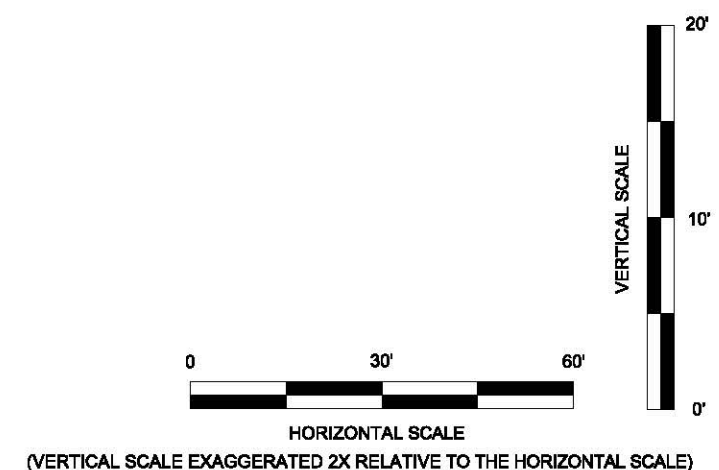
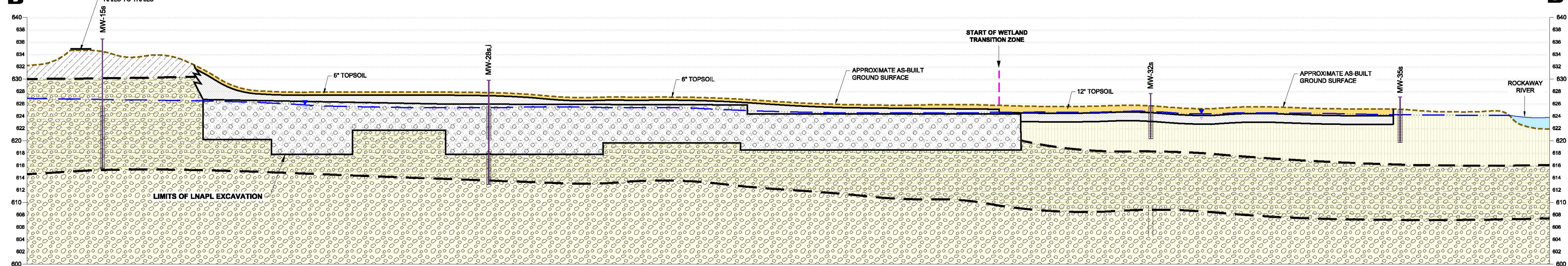


- LEGEND**
- GROUND SURFACE
 - IMPORTED TOPSOIL
 - BACKFILL - RECYCLED MEDIUM TO COARSE SAND FROM TILCON MT. HOPE AND EXCAVATED / REUSED CLEAN SOILS
 - SLURRY MONOLITH WITH REUSED COBBLES AND BOULDERS
 - NATIVE SOILS
 - APPROXIMATE GROUNDWATER ELEVATION

- GENERAL SOIL TYPES**
- FILL - PREDOMINANTLY SAND AND GRAVEL WITH PIECES OF BROKEN BRICK AND CONCRETE, AND SOME MINE TAILINGS
 - PRIMARILY ALLUVIAL WITH SOIL MATRIX CONTAINING SILT, FINE SAND, AND SOME CLAYEY LENSES AND SOME COBBLES, BOLDERS, AND GRAVEL
 - COARSE-GRAINED SOILS WITH VARIABLE MIXTURES OF COBBLES, BOLDERS, SAND, SILT, AND CLAY
 - COARSE-GRAINED SOILS PREDOMINATED BY OUTWASH GRAVELS

West
B

East
B'



- LEGEND**
- APPROXIMATE PROPERTY LINE
 - FENCE LINE
 - TREES
 - RAILROAD TRACKS
 - PROPOSED QUARTERLY MONITORING WELL LOCATION AND NUMBER (s = shallow, i = intermediate, d = deep)
 - SURFACE WATER SAMPLING LOCATIONS (D = DITCH; R = RIVER)
 - PROPOSED GROUNDWATER ELEVATION ONLY WELL
 - EXISTING QUARTERLY MONITORING WELL LOCATION
 - FINAL GRADE CONTOUR LINE
 - STATE OPEN WATERS

NOTES

1. BASE MAP DEVELOPED FROM TOPOGRAPHIC SURVEY PROVIDED BY JAMES M. STEWART, INC. LAND SURVEYORS, DRAWING NO 2793-03.DWG, DATED 02-14-02.

5.					
4.					
3.					
2.					
1.					
NO.	BY	DATE	REVISION	APP'D.	

**L.E. CARPENTER
WHARTON, NEW JERSEY**

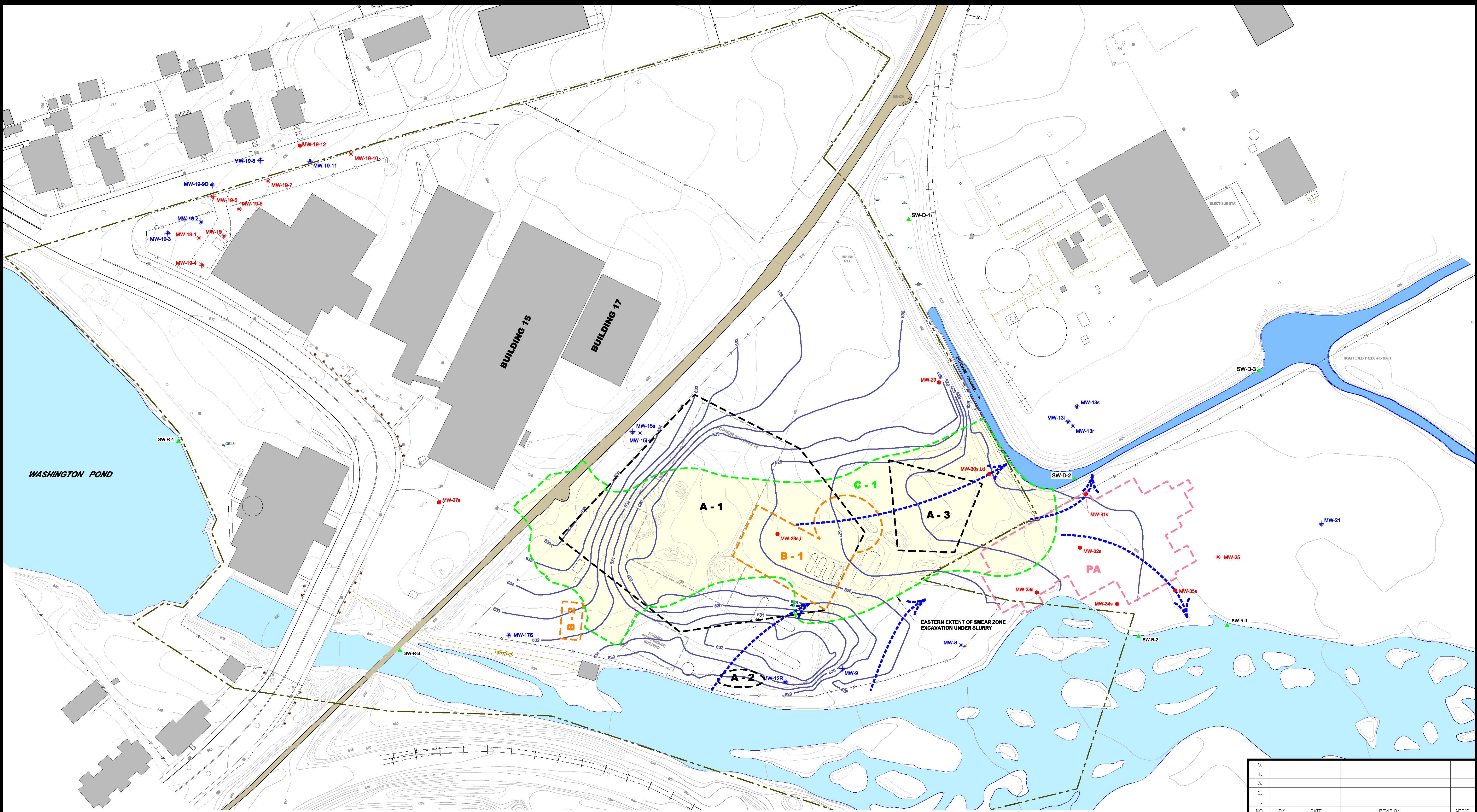
SITE WIDE CROSS SECTIONS

DRAWN BY: SJL	SCALE: SHOWN	PROJECT NO. 6527.13
CHECKED BY: JO	DATE PRINTED: OCTOBER 2005	FILE NO. 6527.13.F12.DWG
APPROVED BY: JD		

FIGURE 5

1143 HIGHLAND DRIVE, SUITE B
ANN ARBOR, MI 48108-2237
PHONE: 313-971-7080
FAX: 313-971-9022

RMT INC.



LEGEND

- APPROXIMATE PROPERTY LINE
- FENCE LINE
- TREES
- RAILROAD TRACKS
- PROPOSED QUARTERLY MONITORING WELL LOCATION AND NUMBER (s = shallow, i = intermediate, d = deep)
- SURFACE WATER SAMPLING LOCATIONS (D = DITCH; R = RIVER)
- PROPOSED GROUNDWATER ELEVATION ONLY WELL
- A-1 AREA WHERE LEAD IMPACTED SOILS > 400 mg/kg (AROUND FORMER BUILDING 14) WERE EXCAVATED
- A-2 AREA WHERE ISOLATED HOT SPOTS OF LEAD IMPACTED SOILS > 400 mg/kg WERE EXCAVATED
- A-3 AREA WHERE LEAD IMPACTED SOILS > 400 mg/kg (IN FORMER WASTE DISPOSAL AREA) WERE EXCAVATED
- B-1 AREA WHERE MULTICOLORED PROCESS WASTE AND DRUMS WERE EXCAVATED
- B-2 AREA WHERE COPPER IMPACTED PROCESS WASTE WAS EXCAVATED
- C-1 AREA WHERE THE LNAPL SMEAR ZONE WAS EXCAVATED
- PA AREA WHERE PCB IMPACTED SOILS WERE EXCAVATED
- AREA OF CEMENT BENTONITE SLURRY MONOLITH
- STATE OPEN WATERS
- POTENTIAL GROUNDWATER FLOW PATHS BASED ON HISTORICAL DATA
- EXISTING QUARTERLY MONITORING WELL LOCATION
- FINAL GRADE CONTOUR LINE

NOTES

1. BASE MAP DEVELOPED FROM TOPOGRAPHIC SURVEY PROVIDED BY JAMES M. STEWART, INC. LAND SURVEYORS, DRAWING NO 2783-03.DWG, DATED 02-14-02.

5.					
4.					
3.					
2.					
1.					
NO.	BY	DATE	REVISION	APP'D.	

L.E. CARPENTER
WHARTON, NEW JERSEY

POST REMEDIAL MONITORING PLAN
PROPOSED MONITORING NETWORK

DRAWN BY:	SJL	SCALE:	PROJECT NO.
CHECKED BY:	JO	SHOWN	6527.17
APPROVED BY:	NC	DATE PRINTED:	FILE NO. 6527.17.04.DWG
DATE:	OCTOBER 2005		

FIGURE 4

1143 HIGHLAND DRIVE, SUITE B
ANN ARBOR, MI 48108-2237
PHONE: 313-971-7080
FAX: 313-971-9022

RMT INC.

Appendix A

Field Forms and Logs



PROJECT NAME: _____

PROJECT NUMBER: _____

PROJECT MANAGER: _____

SITE LOCATION: _____

DATES OF FIELDWORK: _____ **TO** _____

PURPOSE OF FIELDWORK: _____

WORK PERFORMED BY: _____

SIGNED

DATE

CHECKED BY

DATE

PROJECT NAME: 0	DATE:	TIME ARRIVED:
PROJECT NUMBER: 0	AUTHOR: 0	TIME LEFT:

[illegible][illegible][illegible]

DATE _____

**EQUIPMENT SUMMARY**

PROJECT NAME: 0	SAMPLER NAME: 0
PROJECT NO.: 0	

WATER LEVEL MEASUREMENTS COLLECTED WITH:_____
NAME AND MODEL OF INSTRUMENT_____
SERIAL NUMBER (IF APPLICABLE)**PRODUCT LEVEL MEASUREMENTS COLLECTED WITH:**_____
NAME AND MODEL OF INSTRUMENT_____
SERIAL NUMBER (IF APPLICABLE)**DEPTH TO BOTTOM OF WELL MEASUREMENTS COLLECTED WITH:**_____
NAME AND MODEL OF INSTRUMENT_____
SERIAL NUMBER (IF APPLICABLE)**PURGING METHOD**_____
NAME AND MODEL OF PUMP OR TYPE OF BAILER_____
SERIAL NUMBER (IF APPLICABLE)**SAMPLING METHOD**_____
NAME AND MODEL OF PUMP OR TYPE OF BAILER_____
SERIAL NUMBER (IF APPLICABLE)_____
NAME AND MODEL OF FILTRATION DEVICE_____
FILTER TYPE AND SIZE☐ LOW-FLOW SAMPLING EVENT_____
TUBING TYPE**PURGE WATER DISPOSAL METHOD**☐ GROUND ☐ DRUM ☐ POTW ☐ POLYTANK ☐ OTHER _____**DECONTAMINATION AND FIELD BLANK WATER SOURCE**_____
POTABLE WATER SOURCE_____
DI WATER SOURCE_____
SIGNED_____
DATE_____
CHECKED BY_____
DATE



CALIBRATION LOG

PROJECT NAME: 0	MODEL:	SAMPLER:
PROJECT NO.: 0	SERIAL #:	DATE:

PH CALIBRATION CHECK

PH 7 (LOT NUMBER):	PH 4 / 10 (LOT NUMBER):	TIME
/	/	
/	/	
/	/	
/	/	

SPECIFIC CONDUCTIVITY CALIBRATION CHECK

CALIBRATION READING (LOT NUMBER):	TEMPERATURE (°CELSIUS)	CORRECTED CONDUCTIVITY (umhos/cm)	TIME
/			
/			
/			
/			

D.O. CALIBRATION CHECK

CALIBRATION READING (mg/L)	TIME

TURBIDITY CALIBRATION CHECK

CALIBRATION READING (LOT #):	CALIBRATION READING (LOT #):	TIME
/	/	
/	/	
/	/	
/	/	

OXIDATION / REDUCTION POTENTIAL CALIBRATION CHECK

CALIBRATION READING (LOT NUMBER):	TEMPERATURE (°CELSIUS)	CORRECTED ORP (mV)	TIME
/			
/			
/			
/			

PROBLEMS ENCOUNTERED	CORRECTIVE ACTIONS

SIGNED

DATE

CHECKED BY

DATE



IN-SITU TROLL 9000 CALIBRATION LOG

PROJECT NAME:	0	MODEL:	IN-SITU 9000	SAMPLER:	0
PROJECT NO.:	0	SERIAL #:		DATE:	

QUICK CAL SOLUTION

ACCEPTABLE RANGE OF CALIBRATION PARAMETERS SHOWN

LOT #	PH CALIBRATION		ORP CALIBRATION		TIME	DATE
	pH Slope -54 mV < Slope < -62 mV	pH Offset 390 mV < Offset < 450 mV	ORP OFFSET			
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE				
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE				
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE				
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE				
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE				

LOT #	CONDUCTIVITY CALIBRATION		DO CALIBRATION		TIME	DATE
	CONDUCTIVITY 0.33 1/cm < Kcell < 0.39 1/cm	DO SLOPE 15 < Slope < 34	DO Offset 2 nAmps			
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE			
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE			
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE			
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE			
	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE	<input type="checkbox"/> WITHIN RANGE			

TURBIDITY CALIBRATION			
TYPE OF SOLUTION / LOT #	TURBIDITY READING (NTU)/SOLUTION TURBIDITY (NTU)	TIME	DATE
	/		
	/		
	/		
	/		
	/		

PROBLEMS ENCOUNTERED	CORRECTIVE ACTIONS

SIGNED _____

DATE _____

CHECKED _____

DATE _____



PID FIELD CALIBRATION LOG

PROJECT NAME:	0	MODEL:	
PROJECT NUMBER.:	0	LAMP VOLTAGE:	
SAMPLER NAME:	0	SERIAL NO.:	

PID CALIBRATION CHECK

	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:
BATTERY CHECK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ZERO GAS	/	/	/	/	/
SPAN GAS	/	/	/	/	/
AUDIBLE FAN MOTOR CHECK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPONSE CHECK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

PROBLEMS ENCOUNTERED

CORRECTIVE ACTION

SIGNED _____

DATE _____

CHECKED _____

DATE _____

[illegible]

**ALL WATER LEVELS MUST INCLUDE REFERENCE POINT AND TAPE CORRECTION FACTOR
(E.G., 1.1 + 0.00 T/PVC).**

SIGNED

DATE _____

CHECKED

DATE _____

PROJECT NAME: 0	PREPARED		CHECKED	
PROJECT NUMBER: 0	BY: 0	DATE:	BY:	DATE:

SAMPLE ID:		WELL DIAMETER: <input type="checkbox"/> 2" <input type="checkbox"/> 4" <input type="checkbox"/> 6" <input type="checkbox"/> OTHER	
WELL MATERIAL: <input type="checkbox"/> PVC <input type="checkbox"/> SS <input type="checkbox"/> IRON <input type="checkbox"/> OTHER			
SAMPLE TYPE: <input type="checkbox"/> GW <input type="checkbox"/> WW <input type="checkbox"/> SW <input type="checkbox"/> DI <input type="checkbox"/> LEACHATE <input type="checkbox"/> OTHER			

PURGING		TIME:	DATE:	SAMPLE		TIME:	DATE:
PURGE METHOD:	<input type="checkbox"/> PUMP <input type="checkbox"/> BAILER			PH: _____ SU ORP: _____ mv	CONDUCTIVITY: _____ umhos/cm DO: _____ mg/L		
DEPTH TO WATER: _____ T/ PVC				TURBIDITY: _____ NTU			
DEPTH TO BOTTOM _____ T/ PVC				<input type="checkbox"/> NONE <input type="checkbox"/> SLIGHT <input type="checkbox"/> MODERATE <input type="checkbox"/> VERY			
WELL VOLUME: _____ <input type="checkbox"/> LITERS <input type="checkbox"/> GALLONS				TEMPERATURE: _____ °C OTHER: _____			
VOLUME REMOVED _____ <input type="checkbox"/> LITERS <input type="checkbox"/> GALLONS				COLOR: _____ ODOR: _____			
COLOR: _____ ODOR: _____				FILTRATE (0.45 um) <input type="checkbox"/> YES <input type="checkbox"/> NO			
TURBIDITY: _____				FILTRATE COLOR: _____ FILTRATE ODOR: _____			
<input type="checkbox"/> NONE <input type="checkbox"/> SLIGHT <input type="checkbox"/> MODERATE <input type="checkbox"/> VERY				QC SAMPLE: <input type="checkbox"/> MS/MSD <input type="checkbox"/> DUP- _____			
DISPOSAL METHOD <input type="checkbox"/> GROUND <input type="checkbox"/> DRUM <input type="checkbox"/> OTHER				COMMENTS:			

[illegible]

pH: +/- 0.1 COND.: +/- 10 ORP: +/- 10 D.O.: +/- 10 TURB: +/- 10 OR <= 5 TEMP.: +/- 0.5°C

BOTTLES FILLED		PRESERVATIVE CODES												
		A - NONE		B - HNO3		C - H2SO4		D - NaOH		E - HCL		F - _____		
NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED	NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED	NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED
				<input type="checkbox"/> Y <input type="checkbox"/> N										<input type="checkbox"/> Y <input type="checkbox"/> N
				<input type="checkbox"/> Y <input type="checkbox"/> N										<input type="checkbox"/> Y <input type="checkbox"/> N
				<input type="checkbox"/> Y <input type="checkbox"/> N										<input type="checkbox"/> Y <input type="checkbox"/> N

SHIPPING METHOD: _____	DATE SHIPPED: _____	AIRBILL NUMBER: _____
COC NUMBER: _____	SIGNATURE: _____	DATE SIGNED: _____



LOG OF SOIL BORING

PROJECT NAME: 0		SOIL BORING ID:	
PROJECT NUMBER: 0		NORTHING:	SHEET 1 OF
LOGGED BY: 0		EASTING:	SURFACE ELEV.:
PROJECT LOCATION: 0		DATE STARTED:	
DRILLED BY:		DRILLER NAME:	DATE COMPLETED:

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					2.5		
					5		
					7.5		
					10		
					12.5		
					15		
					17.5		
					20		

DRILLING METHOD
DRILL RIG
BORING DIAMETER

WATER LEVEL OBSERVATIONS			
FIRST OCCURRENCE:			
DATE	TIME	DEPTH TO WATER	DEPTH TO CAVE-IN

SIGNED _____ DATE _____

CHECKED _____ DATE _____



LOG OF SOIL BORING

PAGE _____ OF _____

SHEET 2 OF

PROJECT NAME: 0

SOIL BORING ID:

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					22.5		
					25		
					27.5		
					30		
					32.5		
					35		
					37.5		
					40		
					42.5		
					45		

SIGNED _____ DATE _____

CHECKED _____ DATE _____



WELL CONSTRUCTION DIAGRAM

PROJ. NAME: 0		WELL ID:	
PROJ. NO: 0	DATE INSTALLED:	INSTALLED BY: 0	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH BELOW OR ABOVE GROUND SURFACE (FEET)
	TOP OF CASING
	0 GROUND SURFACE
	CEMENT SURFACE PLUG
	GROUT/BACKFILL MATERIAL
	GROUT/BACKFILL METHOD
	GROUT
	BENTONITE SEAL MATERIAL
	BENTONITE SEAL
	TOP OF SCREEN
	FILTER PACK MATERIAL
	BOTTOM OF SCREEN
	BOTTOM OF FILTER PACK
	BENTONITE PLUG
	BACKFILL MATERIAL
	HOLE BOTTOM

Diagram labels: RISER PIPE LENGTH, SCREEN LENGTH

CASING AND SCREEN DETAILS	
TYPE OF RISER: _____	
PIPE SCHEDULE: _____	
PIPE JOINTS: _____	
SOLVENT USED? _____	
SCREEN TYPE: _____	
SCR. SLOT SIZE: _____ INCH	
BOREHOLE DIAMETER: _____ IN. FROM _____ TO _____ FT.	
SURF. CASING DIAMETER: _____ IN. FROM _____ TO _____ FT.	

WELL DEVELOPMENT			
DEVELOPMENT METHOD: _____			
TIME DEVELOPING:	_____	HOURS	
WATER REMOVED:	_____	GALLONS	
WATER ADDED:	_____	GALLONS	
WATER CLARITY BEFORE / AFTER DEVELOPMENT			
CLARITY BEFORE:	_____		
COLOR BEFORE:	_____		
CLARITY AFTER:	_____		
COLOR AFTER:	_____		
ODOR (IF PRESENT) _____			
WATER LEVEL SUMMARY			
SWE MEASUREMENT		DATE	TIME
BEFORE DEVELOPING:	T/PVC		
AFTER DEVELOPING:	T/PVC		
OTHER	T/PVC		
OTHER	T/PVC		

NOTES:

PROTECTIVE COVER AND LOCK INSTALLED ☐ YES ☐ NO
PERMANENT, LEGIBLE WELL LABEL ADDED ☐ YES ☐ NO



WELL CONSTRUCTION DIAGRAM

PROJ. NAME: 0	WELL ID:	
PROJ. NO: 0	DATE INSTALLED: 0	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH BELOW OR ABOVE GROUND SURFACE (FEET)
	0 GROUND SURFACE
	TOP OF CASING
	CEMENT SURFACE PLUG
	GROUT/BACKFILL MATERIAL
	GROUT/BACKFILL METHOD
	GROUT
	BENTONITE SEAL MATERIAL
	BENTONITE SEAL
	TOP OF SCREEN
	FILTER PACK MATERIAL
	BOTTOM OF SCREEN
	BOTTOM OF FILTER PACK
	BENTONITE PLUG
	BACKFILL MATERIAL
	HOLE BOTTOM

NOTES:

CASING AND SCREEN DETAILS	
TYPE OF RISER:	
PIPE SCHEDULE:	
PIPE JOINTS:	
SOLVENT USED?	
SCREEN TYPE:	
SCR. SLOT SIZE:	INCH
BOREHOLE DIAMETER:	IN. FROM TO FT.
	IN. FROM TO FT.
SURF. CASING DIAMETER:	IN. FROM TO FT.
	IN. FROM TO FT.

WELL DEVELOPMENT	
DEVELOPMENT METHOD:	
TIME DEVELOPING:	HOURS
WATER REMOVED:	GALLONS
WATER ADDED:	GALLONS
WATER CLARITY BEFORE / AFTER DEVELOPMENT	
CLARITY BEFORE:	
COLOR BEFORE:	
CLARITY AFTER:	
COLOR AFTER:	
ODOR (IF PRESENT)	

WATER LEVEL SUMMARY			
SWE MEASUREMENT		DATE	TIME
BEFORE DEVELOPING:	T/PVC		
AFTER DEVELOPING:	T/PVC		
OTHER	T/PVC		
OTHER	T/PVC		

PROTECTIVE COVER AND LOCK INSTALLED ☐ YES ☐ NO
PERMANENT, LEGIBLE WELL LABEL ADDED ☐ YES ☐ NO

PROJECT NAME:	0
PROJECT NO.:	0

SAMPLER NAME: 0

DATE:

[illegible]

DATE _____

Appendix B

USEPA & NJDEP Low Flow Sampling Guidance



Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

by Robert W. Puls¹ and Michael J. Barcelona²

Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites. One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives. This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling.

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I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water. Large water-bearing

units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased. This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic units. With time it became apparent that conventional water supply generalizations of *homogeneity* did not adequately represent field data regarding pollution of these subsurface resources. The important role of *heterogeneity* became increasingly clear not only in geologic terms, but also in terms of complex physical,

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Director

chemical and biological subsurface processes. With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and *aquitards* or low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths.

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today: aquifer heterogeneity and colloidal transport. Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g., 3-6 m) typically installed at hazardous waste sites to detect and monitor plume movement over time. Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987; McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988; Penrose et al., 1990). Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third *phase* as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990; McCarthy and Degueldre, 1993; Backhus et al., 1993; U. S. EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm. The most commonly observed mobile particles include: secondary clay minerals; hydrous iron, aluminum, and manganese oxides; dissolved and particulate organic materials, and viruses and bacteria.

These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the *total* mobile contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias *naturally* suspended particle concentrations.

Currently the most common ground-water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artifactual particles which produce an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques.

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic *push* technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential baseline data requirements. Detailed soil and geologic data are required prior to and during the installation of sampling points. This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended. With this information (together with other site characterization data) and a clear understanding of sampling

objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with *hybrid* variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

- 1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;
- 2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and
- 3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term *representativeness* applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

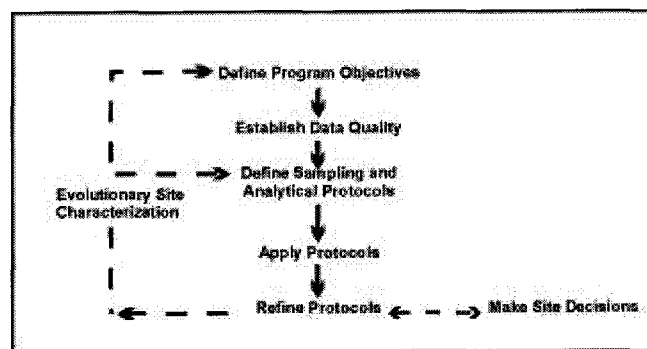


Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.

1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren't statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these *over-sampling* concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

C. Sampling Point Design and Construction

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program's data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few

feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

2) Flexibility of Sampling Point Design

In most cases *well-point* diameters in excess of 1 7/8 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that *short* (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. *Short*, of course, is relative to the degree of vertical water quality variability expected at a site.

3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than *direct-push* technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality *recovery* period.

III. Definition of Low-Flow Purging and Sampling

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point. Low-

flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

A. Low-Flow Purging and Sampling

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min. The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques. The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used. Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval. Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling.

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques. If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled. At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective.

B. Water Quality Indicator Parameters

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxida-

tion-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity. Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization. Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging

In general, the advantages of low-flow purging include:

- samples which are representative of the *mobile* load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control;

- reduced stress on the formation (minimal drawdown);
- less mixing of stagnant casing water with formation water;
- reduced need for filtration and, therefore, less time required for sampling;
- smaller purging volume which decreases waste disposal costs and sampling time;
- better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are:

- higher initial capital costs,
- greater set-up time in the field,
- need to transport additional equipment to and from the site,
- increased training needs,
- resistance to change on the part of sampling practitioners,
- concern that new data will indicate a *change in conditions* and trigger an *action*.

IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors' (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986; Puls and Barcelona, 1989; Puls et. al. 1990, 1992; Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of *representative* ground-water samples include: mixing of the stagnant casing and *fresh* screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to

sampling, it is recommended that an in-line water quality measurement device (e.g., flow-through cell) be used to establish the stabilization time for several parameters (e.g., pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling:

- use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well;
- maximize tubing wall thickness, minimize tubing length;
- place the sampling device intake at the desired sampling point;
- minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
- make proper adjustments to stabilize the flow rate as soon as possible;
- monitor water quality indicators during purging;
- collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system.

B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer's recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing. Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation.

D. Pump Type

The use of low-flow (e.g., 0.1-0.5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site. Bailers are inappropriate devices for low-flow sampling.

1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and minimal disturbance of the sample across a range of *low* flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause *significant* drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be of a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other *grab* type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of *stagnant* water in the casing and the *dynamic* water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1991), U. S. EPA (1992), Parker (1994) and Thurnblad (1994).

E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over any other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screen with the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and resulting purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a *fix* for poor sampling practices, and field-filtering of certain constituents should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally *dissolved* [i.e., samples filtered with 0.45 μ m filters]) concentrations of major ions and trace metals, 0.1 μ m filters are recommended although 0.45 μ m filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO₂ composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g. oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 μ m). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer's recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, a filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality

indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within ± 0.1 for pH, $\pm 3\%$ for conductivity, ± 10 mv for redox potential, and $\pm 10\%$ for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

H. Sampling, Sample Containers, Preservation and Decontamination

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g., Fe^{2+} , CH_4 , $\text{H}_2\text{S}/\text{HS}^-$, alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analytes of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U. S. EPA, 1992] or EPA SW-846 [U. S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or

introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

I. Blanks

The following blanks should be collected:

- (1) field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.
- (2) equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.
- (3) trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

V. Low-Permeability Formations and Fractured Rock

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of

the well screen. This may require repeated recovery of the water during purging while leaving the pump in place within the well screen.

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected; i.e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i.e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device.

A. Low-Permeability Formations (<0.1 L/min recharge)

1. Low-Flow Purging and Sampling with Pumps

- a. "portable or non-dedicated mode" - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements). After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.
- b. "dedicated mode" - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized. Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

2. Passive Sample Collection

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining "representative" samples. Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives.

B. Fractured Rock

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most "representative" samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or other geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in "dedicated mode" or use a passive sampling device which can isolate the identified water-bearing fractures.

VI. Documentation

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum: information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and "Ground Water Sampling Workshop -- A Workshop Summary" (U. S. EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the "useability" of the sampling data.

VII. Notice

The U.S. Environmental Protection Agency through its Office of Research and Development funded and managed the research described herein as part of its in-house research program and under Contract No. 68-C4-0031 to Dynamac Corporation. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Project _____ Site _____ Well No. _____ Date _____
Well Depth _____ Screen Length _____ Well Diameter _____ Casing Type _____
Sampling Device _____ Tubing type _____ Water Level _____
Measuring Point _____ Other Infor _____

Sampling Personnel _____

[illegible]

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $\text{Vol}_{\text{cyl}} = \pi r^2 h$, $\text{Vol}_{\text{sphere}} = 4/3 \pi r^3$

Project _____ Site _____ Well No. _____ Date _____
Well Depth _____ Screen Length _____ Well Diameter _____ Casing Type _____
Sampling Device _____ Tubing type _____ Water Level _____
Measuring Point _____ Other Infor _____

Sampling Personnel _____

[illegible]

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $\text{Vol}_{\text{cyl}} = \pi r^2 h$, $\text{Vol}_{\text{sphere}} = 4/3\pi r^3$

Appendix C

QAPP [Version 2]

**QUALITY ASSURANCE PROJECT PLAN
(QAPP) [VERSION 2]**

**L.E. CARPENTER & COMPANY
WHARTON, MORRIS COUNTY, NEW JERSEY
USEPA ID NO. NJ002168748**

October 2005

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Acronyms

AA	Atomic Absorption Spectrophotometer
AOC	Administrative Order of Consent
ASTM	American Standards for Testing Materials
BNA	Base-neutral/acid extractables (semivolatile organic compounds)
BETX	Benzene, ethylbenzene, toluene, xylene
CCB	Continuing calibration blank
CCV	Continuing calibration verification
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund), as amended by the Superfund Amendments and Reauthorization Act (SARA)
CLP	Contract Laboratory Program
COPC	Constituent of potential concern
CRA	Contract Required Atomic Absorption Spectrophotometer Standard
CRDL	Contract Required Detection Limit
CRI	Contract Required Inductively Coupled Plasma Spectrophotometer Standard
CRQL	Contract Required Quantitation Limit
CRL	Central Regional Laboratory
CVAA	Cold vapor atomic absorption spectrophotometer
DEHP	di(2-ethylhexyl)phthalate
DO	Dissolved oxygen
DQO	Data Quality Objective
Eh	Redox potential
FSP	Field Sampling Plan
GC	Gas chromatograph
GFAA	Graphite furnace atomic absorption spectrophotometer
HSR	Health and Safety Representative
ICB	Initial calibration blank
ICP	Inductively coupled plasma emission spectrophotometer

ICS	Interference check sample
ICV	Initial calibration verification
LRA	Linear range analysis
MDL	Method detection limit
MS/MSD	Matrix spike/matrix spike duplicate
NCP	National Contingency Plan
NIST	National Institute for Standards and Technology
NJDEP	New Jersey Department of Environmental Protection
NTU	Nephelometric turbidity unit
O&M	Operation and Maintenance
ORP	Oxidation reduction potential
OSC	On-site Coordinator
PCB	Polychlorinated biphenyl
PRMP	Post Remedial Monitoring Plan
QA	Quality Assurance
QAM	Quality Assurance Manager
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAS	Routine analytical services
RI/FS	Remedial Investigation and a Feasibility Study
RMT	RMT, Inc.
ROD	Record of decision
RPD	Relative percent difference
RPM	Remedial Project Manager
SAS	Special analytical services
SOP	Standard Operating Procedure
TDS	Total dissolved solids
TSS	Total suspended solids
TOC	Total organic carbon
USEPA	United States Environmental Protection Agency

VOA	Volatile organic analysis
VOC	Volatile organic compound

Section 1

Project Description

1.1 Introduction

This Quality Assurance Project Plan (QAPP) has been prepared to supercede the May 2001 QAPP included as Appendix A in the *Workplan for Supplemental Investigation of Natural Attenuation of Dissolved Constituents in Groundwater* (RMT, May 2001). All previous investigations have referenced the approved May 2001 QAPP prepared by RMT; however, the proposed scope for post-remedial monitoring warrants significant QAPP modification.

The USEPA requires all environmental monitoring and measurement efforts mandated or supported by the USEPA be centrally managed by a QA program to ensure that the precision, accuracy, completeness, and representativeness of the RI/FS data are known and documented. This QAPP describes the protocols that will be followed for collecting and handling samples, sample storage, chain-of-custody procedures, and laboratory and field analyses.

This QAPP was prepared in general accordance with the following guidance documents:

- EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, EPA /QA/R-5. (Draft), October 1997.
- Data Quality Objectives Process for Superfund, Interim Final Guidance, OSWER Directive 9355.9-01, September 1993.
- EPA NEIC Policies and Procedures Manual,, EPA 330/978-001-R, May 1986.
- USEPA Contract laboratory Program National Functional Guidelines for Organic Data Review, EPA 540/R-99-008, October 1999.
- USEPA Contract laboratory Program National Functional Guidelines for Inorganic Data Review, EPA 540/R-94/013

1.2 Site Description and Background

A description and background of the site is presented in Section 1 of the Post Remedial Monitoring Plan (PRMP).

1.3 Investigative Objectives

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide results that address the data

quality objectives and produce data that are legally defensible. Specific procedures for natural attenuation sampling, chain-of-custody, laboratory instrument calibration, laboratory analysis, reporting of data, internal quality control, audits, preventive maintenance of field equipment, and corrective action are described in this QAPP. The purpose of this QAPP is to describe the project objectives and organization, functional activities and quality assurance and quality control protocols that will be used to achieve the desired data quality objectives (DQOs) at the L.E. Carpenter Site. The general investigative objectives of the post-remedial monitoring program have been described in the PRMP.

1.3.1 Analyses

To meet the data needs, the testing program consists of the following analyses to be performed on groundwater samples as outlined in the above documents:

- BTEX Compounds (benzene, toluene, ethylbenzene, xylene)
- DEHP [di-ethyl-hexyl-phthalate]
- Ammonia, nitrate, sulfate, dissolved lead, and total phosphorus
- Alkalinity, ferrous iron, CO₂, and dissolved oxygen (DO)
- Methane,
- pH, Eh, specific conductance, temperature, turbidity,
- Heterotrophic bacteria plate count
- Total suspended solids (TSS) and Total dissolved solids (TDS)
- Field physical testing for groundwater level

1.3.2 Field Parameters and Uses

Sampling procedures specific to low-flow sampling are described in detail in Attachment 1. Other field instrument calibration and analytical procedures are presented within the O&M manuals provided by the manufacturer of the equipment being used.

Temperature, specific conductance, dissolved oxygen (DO), pH, Eh, and turbidity will be measured from all groundwater samples and be used as indicators of well purging stability as well as in later natural attenuation evaluations.

1.3.3 Laboratory Parameters and Uses

All laboratory analyses will be performed by Lancaster Laboratories of Lancaster, Pennsylvania (Lancaster) [State of New Jersey Laboratory Certification No. PA011].

BTEX compounds will be analyzed using USEPA Method 602. DEHP will be analyzed by Method 625. These organic compounds constitute the contaminants of concern in the groundwater.

Additional parameters, sulfate, ammonia, nitrate, phosphorus, carbon dioxide, dissolved lead, and methane, will be analyzed to determine natural attenuation potential and rate of attenuation.

1.3.4 Intended Data Uses

The PRMP details the intended data uses, which are summarized briefly here. This sampling program has been developed to provide the following information:

1. Determine the post remedial lateral and vertical extent and mass of remaining dissolved constituents of concern in groundwater.
2. Quantify the extent to which natural attenuation is reducing the remaining mass of dissolved constituents in the groundwater
3. Provide documentation to amend the existing record of decision (ROD) remedy for groundwater from pump and treat to natural attenuation.

1.4 Sample Network Design and Rationale

The sample locations and rationale for selected sample locations are described in Section 2 of the Monitoring Plan. Figure 4 of the Monitoring Plan presents sampling locations. The sample analytical parameters are indicated in Table 1 below.

Table 1
Field and Laboratory Analyte List

FIELD METHODOLOGIES		ANALYTES	
Purge Stability using a micro purge cell, probe and electrodes		DO, Eh, pH, Temperature, Turbidity, Specific Conductance	
Natural Attenuation criteria using a Hach field kit		Ferrous Iron, CO ₂ , Alkalinity	
LABORATORY METHODOLOGIES		ANALYTES	
Contaminants of Concern (COC)	Organics	BTEX	
		DEHP	
Natural Attenuation Criteria	Anions	Sulfate, Nitrate-N	
	Cations	Ammonia-N, Phosphorus, dissolved Lead	
	Other	Heterotrophic Plate Count, TSS, TDS	
	Breakdown gases	Methane	

1.5 Data Quality Objectives

Data Quality Objectives are qualitative and quantitative statements which specify the quality of the data required to support decisions made during evaluation activities and are based on the end uses of the data to be collected. As such, different data uses may require different levels of data quality. There are two analytical levels, which address various data uses and the QA/QC effort and methods required to achieve the desired level of quality. For this post-remedial natural attenuation evaluation these are as follows:

1.5.1 Screening Data

These data are generated by less precise analytical methods with less rigorous sample preparation than those with definitive level methods. Sample preparation steps may be restricted to simple procedures, such as dilution with a solvent, instead of elaborate extraction/digestion and cleanup. Screening data provide analyte identification and quantification, although the quantification may be relatively imprecise. A portion of screening data may be confirmed using analytical methods and QA/QC procedures and criteria associated with definitive data. Screening data without associated confirmation data are not considered to be data of known quality.

Screening quality data will be used for field-measured parameters such as pH, temperature, specific conductance, dissolved oxygen, alkalinity (field measurement), carbon dioxide (field measurement), ferrous iron (field measurement), redox potential (ORP; Eh), turbidity, depth to groundwater, and health and safety monitoring. These data will be used for determining the progress of the monitoring well purge process, general groundwater quality, rate of natural attenuation, and possibly as input to computer fate and transport models.

1.5.2 Definitive Data

These data are generated using rigorous analytical methods, such as approved USEPA methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (*e.g.*, chromatograms, spectra, digital values) in the form of paper printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location as long as QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error or precision of the analytical method must be determined.

The following data will be collected to meet definitive data quality objectives:

- Groundwater to be analyzed for BTEX and DEHP in accordance with USEPA analytical protocols and data validation procedures.
- Ammonia, sulfate, nitrate, phosphorus, dissolved lead, TSS, TDS, and heterotrophic bacteria plate count will be analyzed in accordance with USEPA-approved analytical methods and laboratory Standard Operating Procedures (SOPs). These data will be used to evaluate the potential for natural attenuation.
- Methane will be analyzed using a headspace (SW-846 Method 3810) and laboratory SOPs. This data will be used to evaluate the potential for natural attenuation.

Section 2

Project Organization and Responsibilities

2.1 Identification of Key Project Personnel

The monitoring well and groundwater sampling will be performed by RMT, Inc, on behalf of the L.E. Carpenter & Company. The key management and technical staff responsible for the execution of the PRMP are:

Nicholas J. Clevett, **Project Manager**

James J. Dexter, CPG, **Project Coordinator**

Jennifer Overvoorde, **Technical and Field Coordinator**

Eric Vincke, **Environmental Scientist [Field Personnel]**

Greg Graf, **QA/QC Officer and Data Validation Coordinator**

Personnel involved in the investigation, and in the generation of data as a result of investigation activities, become a part of the overall Project Quality Assurance program. Within that program, the following individuals have specific responsibilities: the Project Coordinator, the Technical Coordinator and the field personnel. Specific laboratory personnel with Quality Assurance/Quality Control responsibilities include the Laboratory Quality Assurance Officer and the Laboratory Scientists and Technicians.

2.2 USEPA Region II and NJDEP Remedial Project Managers (RPMs)

The USEPA Region II Project Manager and NJDEP Project Manager are Mr. Stephen Cipot and Mr. Anthony Cinque respectively. These two individuals are the primary project points of contact for their respective agencies and have the responsibility for coordinating regulatory status and issues within/between the USEPA Region II and the NJDEP, and ensuring that all natural attenuation activities comply with applicable standards and technical guidance.

2.3 RMT Project Manager

Nicholas Clevett will provide overall management of all project initiatives, and will establish and communicate schedules and budgets to both technical staff and the technical coordinator.

He will aid the project coordinator with all USEPA and NJDEP initiatives, and will also assist both the project and technical coordinators with overall technical direction.

2.4 RMT Project Coordinator

James Dexter will provide technical direction, review RMT's performance on this project, and will provide overall senior QA/QC. He will also provide input concerning Superfund procedures and conformance with the National Contingency Plan (NCP). He will also coordinate activities with the USEPA and the NJDEP as appropriate.

2.5 RMT Technical Coordinator

Jennifer Overvoorde will be responsible for implementation of the Monitoring Plan and will coordinate technical staff assignments both in-house and in the field, and as necessary, will assist the project manager with USEPA and NJDEP contact regarding status, technical and regulatory issues.

2.6 RMT Field Coordinator

The Field Coordinator will be the principal field team member primarily responsible for project field coordination and in-field Quality Assurance activities. The Field Coordinator will guide the field personnel in achieving a thorough understanding of the project Quality Assurance Plan and their respective roles relative to one another within the established project framework. The Field Coordinator will also act as the site Health and Safety Representative (HSR).

The Field Coordinator is also responsible for the day-to-day activities of contractor field personnel. In this capacity, the Field Coordinator is responsible for the Quality Assurance of daily project activities and the maintenance of the Quality Assurance Project Plan. Further responsibilities include the review of field notebooks, driller's logs, and other field-related documentation.

2.7 RMT Field Personnel

These environmental staff will be responsible for measuring and recording field parameters; installing monitoring points, collecting, labeling, and transporting samples; and conducting in-field measurements, in accordance with the Monitoring Plan and QAPP. They will report to the Field Coordinator.

2.8 RMT Laboratory Coordinator

The Laboratory QA/QC Coordinator will be responsible for ensuring that applicable QA/QC procedures are followed. This will include reviewing QA/QC procedures and documentation, and directing the data validation and assessment activities, also is responsible for internal performance and system audits.

Section 3

Quality Assurance Objectives for Measurement Data

Data quality requirements are based on the intended use of the data, the measurement process, and the availability of resources. Data quality requirements include detection limits, accuracy, and precision Quality Assurance protocols for the analytical methods to be used and the analyses to be conducted. Specific guidelines for accuracy, precision, completeness, and representativeness are discussed in the following subsections. Field blank, trip blank, decontamination evaluation (*i.e.*, "rinsate" or "equipment") blanks, atmospheric blanks, and field duplicates described in Section 10 of this QAPP will be subjected to the same Quality Assurance objectives as samples.

3.1 Accuracy

Accuracy is defined as the degree of agreement of a measurement or average of measurements with an accepted reference or true value. Accuracy control limits for the analyses are included in the laboratory SOPs.

The project-specific QA objectives established for accuracy are expressed in the following parameters.

3.1.1 Recovery of Analyte Spikes

Accuracy of laboratory results will be assessed for compliance with the established QC criteria using the analytical results of method blanks, reagent/preparation blanks, matrix spike/matrix spike duplicate samples, field blanks, and trip blanks.

To ensure the accuracy of the analytical procedures, an environmental sample will be randomly selected and spiked with a known amount of the analyte or analytes to be evaluated. In general, a sample spike is included in every set of 20 samples tested on each instrument. The spike sample will then be analyzed. An increase in the analyte concentration due to the spike addition, compared to the concentration in the unspiked sample, determines the percent recovery. The percent recovery (%R) of matrix spike samples will be calculated as follows:

$$\text{Spike Recovery (\%)} = \left(\frac{\text{ug X found in spiked sample} - \text{ug X in native sample}}{\text{ug X added to sample}} \right) \times 100\%$$

Spike recovery data is used to check for possible sample matrix interference and analytical bias. The objectives for the spike recovery from aqueous matrices are given in the USEPA-approved methods and laboratory SOPs.

3.1.2 Reference Materials

Reference materials used as calibration standards or surrogate compounds will be certified, commercially available materials.

3.1.3 Instrument Performance

Instruments used in this project will be checked each day that samples are analyzed to demonstrate instrument performance. The QA objectives for instrument sensitivity, calibration, and performance are established in the USEPA-approved analytical methods and laboratory SOPs. These methods are listed in Section 8 of this QAPP.

3.1.4 Recovery of Surrogates

Surrogate compound recovery is utilized to evaluate proper performance of the analytical method and/or possible matrix interference to the analytical method for organic compounds.

The recovery of a surrogate compound (S) added to a sample will be defined as follows:

$$\text{Recovery \%} = \frac{\text{ug S found in sample}}{\text{ug S added to sample}} \times 100\%$$

This equation assumes that the surrogate is not present in the sample. The objectives for recovery of surrogates from aqueous matrices are given in the USEPA-approved methods and laboratory SOPs.

3.2 Precision

Precision is defined as a measure of mutual agreement among individual measurements of a sample property. Comparing analytical results between MSs/MSDs for organic analysis, and laboratory duplicate analyses for inorganic analysis will assess precision of laboratory analyses. The project QA objectives established for precision are expressed in the following parameters.

3.2.1 Analysis of Standards

One of the QA objectives for this project is that each initial calibration curve and subsequent (*i.e.*, "continuing") calibration standards meet or exceed the minimum QA criteria established in the USEPA-approved methods and laboratory SOPs.

3.2.2 Analysis of Spiked Samples

A second QA objective for this project is that the results of spiked samples (*i.e.*, matrix spikes) and spiked sample duplicates (*i.e.*, matrix spike duplicates) be within the advisable recovery and Relative Percent Difference (RPD) limits specified in the USEPA-approved methods and laboratory SOPs.

3.2.3 Analysis of Duplicate Samples

A third QA objective for this project is that analyte concentrations be comparable between duplicate samples. This includes 1) duplicate samples collected in the field, 2) duplicate analyses resulting from matrix spike and matrix spike duplicate samples, and 3) results generated from multiple analyses of a sample performed at the laboratory.

A measure of precision is RPD of two analyses of the same sample. This measure is applied as a quality control criterion to the recovery of organic matrix spike compounds. Splitting of the sample allows the determination of the precision of the preparation and analytical techniques associated with the duplicate sample. The RPD will be calculated using the equation:

$$\% RPD = \frac{S - D}{(S + D)/2} \times 100\%$$

RPD criteria for organic matrix spike compounds are given in the USEPA-approved methods and laboratory SOPs.

3.3 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected under normal conditions. It is expected that 95 percent or more of all samples tested via USEPA and SOP methods will provide data meeting QC acceptance criteria. Following completion of the analytical testing, the percent completeness will be calculated by the following equation:

$$\% \text{ Completeness} = \frac{\text{Number of valid results}}{\text{Number of possible results}} \times 100\%$$

3.4 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness is a qualitative parameter that is dependent on the proper design of the sampling program and the proper laboratory protocol. The sampling program described in the Monitoring Plan was designed to provide data that is representative of site conditions. Sampling sites, sampling frequency, sampling procedures, and sampling equipment are addressed in the Monitoring Plan to obtain representative samples. Other procedures such as sample preservation, appropriate sample containers, sample hold times, and analytical procedures are addressed in this QAPP.

3.5 Comparability

Comparability expresses the confidence with which one data set can be compared with another. The extent to which existing and planned analytical data will be comparable depends on the similarity of sampling and analytical methods. The procedures used to obtain the planned analytical data, as documented in this QAPP, are expected to provide comparable data. These new analytical data, however, may not be directly comparable to existing data because of differences in procedures and QA objectives.

Data acquired for different purposes using different analytical methods, or different DQOs, may not be directly comparable. Samples analyzed using approved methods are expected to be comparable.

Section 4

Sampling Procedures

Specific field procedures for purging wells and actual sample collection procedures are addressed in the attached SOPs for low-flow sampling. Details on sample designation and location are given in the Monitoring Plan. The collection of QC blanks, duplicate samples, and spike samples will be discussed in Section 10 of this QAPP.

Sample container, preservation procedures and holding time requirements are presented in Table 2. Pre-cleaned sample containers will be obtained from the analytical laboratory.

Table 2
Water Sample Containers, Preservatives, and Holding Times

PARAMETER	CONTAINER(S)*	MINIMUM SAMPLE VOLUME	FIELD PRESERVATION METHOD	HOLDING TIME ⁽¹⁾
Volatile organics (<i>i.e.</i> , BTEX)	3 x 40 mL glass VOA vials with Teflon [®] ⁽²⁾ septum	1 x 40 mL VOA vial	Cool to 4°C, add HCl to pH < 2; protect from light	14 days (sample should remain on-site less than 24 hours)
Semivolatile organics (<i>i.e.</i> , DEHP)	1 x 1,000 mL amber bottle ⁽⁴⁾	1,000 mL	Cool to 4°C	7 days to extraction 40 days from extraction to analysis
Methane	2 x 40 mL VOA vials with Teflon [®] septum ⁽²⁾	1 x 40 mL VOA vial	Cool to 4°C; protect from light; may be preserved with HCl to pH < 2	7 days if unpreserved 14 days if preserved
Phosphorus	Use an aliquot from the alkalinity bottle	100 mL	Cool to 4°C	28 days
Lead (dissolved)	1 x 500 mL high-density polyethylene bottle	500 mL	Cool to 4°C, add HNO ₃ to pH < 2	6 months
Sulfate	Use an aliquot from the alkalinity bottle	100 mL	Cool to 4°C	28 days
Ammonia-N	1 x 1000 mL high-density polyethylene bottle ⁽³⁾	100 mL	Cool to 4°C, add H ₂ SO ₄ to pH < 2	28 days
Nitrate-N	1 x 250 mL high-density polyethylene bottle ⁽³⁾	100 mL	Cool to 4°C, add H ₂ SO ₄ to pH < 2	28 days
Temperature, Eh, pH, Specific Conductivity, DO, Ferrous Iron, Turbidity, alkalinity, CO ₂	--	--	--	Immediately after sample collected
Heterotrophic Plate Count	120 mL sterile plastic	10 mL	Cool to 4°C, add Na ₂ S ₂ O ₃	24-hours
TSS	250 mL G/P	250 mL	Cool to 4°C	7 days
TDS	250 mL G/P	250 mL	Cool to 4°C	7 days
⁽¹⁾ Starting from time of sample collection. ⁽²⁾ Collect three extra containers for MS/MSD samples. ⁽³⁾ Collect one extra container for sample spike and duplicate analyses. ⁽⁴⁾ Collect two extra containers for MS/MSD samples.				

Section 5

Sample Custody

Chain-of-custody documentation enables possession of a sample to be traced from sample collection through analysis and disposal. A sample is considered under custody if:

- the item is in a person's possession;
- the item is in that person's view after being in his or her possession;
- the item was in that person's possession and then placed in a secured location; or
- the item is in a designated and identified secure area.

The field technician performing sample collection activities will be responsible for sample custody in the field. The laboratory sample custodian and analysts will be responsible for custody of the sample at the laboratory.

5.1 Field Chain-of-Custody

Prior to collecting samples in the field, the Field Personnel will obtain the sample bottles necessary for the field operation. Field Personnel will label each sample collected, filling in the appropriate information in waterproof ink. The field sampler will be responsible for collecting the samples and for logging the samples into assigned field notebooks. The field samplers will complete and verify the Chain-of-Custody forms. A sample Chain-of-Custody form can be found in Attachment 2. A copy of the Chain-of-Custody will be placed in the project files and the original will accompany the samples to the laboratory. The identity of field duplicate samples will not be disclosed to the analytical laboratory. Sample analysis request forms will be prepared by the RMT Laboratory Coordinator, or prepared by Field Personnel and reviewed by the RMT Laboratory Coordinator. The analytical request forms will accompany samples, or precede delivery of samples, to the laboratory.

5.2 Transfer of Custody and Sample Shipment

Shipping containers will be sealed and accompanied by the Chain-of-Custody record, with appropriate signatures. The transfer of custody is the responsibility of the Field Personnel and the laboratory staff. The procedures to be implemented are as follows:

- Place completed chain-of-custody forms in a plastic bag, seal the bag, and tape it to the inside cover of the shipping container. After the samples are iced, seal the coolers with strapping tape and custody seals, add the date to the custody form, and ship the coolers to

Lancaster using an overnight delivery service. Identify common carriers or intermediate individuals on the chain-of-custody form, and retain copies of all bills-of-lading. When the samples are received in the laboratory, handle and process them in accordance with the procedures in laboratory SOPs, or specified analytical methods.

5.3 Laboratory Custody Procedures

In the laboratory, a sample custodian will be assigned to receive the samples. Upon receipt of a sample, the custodian will inspect the condition of the samples, reconcile the sample(s) received against the Chain-of-Custody record, log in the sample(s) in the laboratory log book, and store the sample(s) in a secured sample storage room or cabinet maintained at an appropriate temperature until assigned to an analyst for analysis. Custody will be maintained until the sample is discarded.

The sample custodian will inspect the sample for any leakage from the container. A leaky multi-phase sample will not be accepted for analysis as this sample would no longer be a representative sample.

The custodian will examine whether the sample bottle seal is intact or broken, since a broken seal may mean sample tampering and may make analytical results inadmissible in court as evidence. The RMT Laboratory QA/QC Coordinator will be promptly notified of broken seals so that appropriate action may be taken (*e.g.*, collect another sample).

When samples requiring preservation by either acid (except samples for volatile organic compound analysis) or base are received at the laboratory, the pH will be measured and documented. The Laboratory sample custodian will adjust the pH, if necessary, and the RMT Laboratory QA/QC Coordinator will be promptly notified of the pH adjustment so that sample collection procedures can be reviewed to determine if a modification is necessary.

Discrepancies observed between the samples received, the information that is on the Chain-of-Custody record, and the sample analysis request sheet will be resolved before the sample is assigned for analysis. The RMT Laboratory QA/QC Coordinator will be informed of any such discrepancy as well as its resolution. Results of the inspection will be documented in the laboratory sample logbook. Discrepancies will be documented in the analytical case narrative, as appropriate.

5.4 Sample Labels and Seals

Sample labels as shown in Attachment 3 will be affixed to each sample bottle before sample collection. At a minimum, the sample label will contain the following:

- Client - Job Name/Project Number,

- Sample Identification,
- Date and Time Collected (except for duplicate samples),
- Sampler's Signature (or initials), and
- Preservatives Added.

Section 6

Sampling Site Location and Sampling Activity Identification

Details on field documentation procedures are outlined in the Monitoring Plan and generally in the text below.

6.1 Field Logbooks

Information pertinent to fieldwork will be recorded in field logbooks. Field logbooks will be bound, with consecutively numbered pages. The pages will be dated and signed by the person who is recording the information. Unused space at the bottom of a page will be crossed through. Work sketches or phrases that are recorded but deemed incorrect will be marked through in such a way as to still be legible, yet obviously struck from the text. Mark-throughs will be initialed and dated by the person striking the item.

Persons leading a sampling team or performing a distinct task will be issued a field logbook by the RMT Field Coordinator. That person will maintain the logbook during associated fieldwork. At the conclusion of the various phases of the fieldwork, the field books will be collected and reviewed by the Field Coordinator.

6.2 Photographs

Sampling site locations will be identified on a site map. The location will be cross-referenced in the field notebook as to the identification of samples collected from the site location.

Photographs of the sampling site location and the activities occurring at a specific location will be made. Photographs will be cross-referenced with an identification/explanation narrative in the field notebook.

Section 7

Calibration Procedures

7.1 Laboratory Calibration

The calibration procedures to be used for this project are summarized below, and will follow the analytical methods specified in Section 8 of this QAPP.

7.1.1 Instrument Performance and Tune

Prior to analysis of each set of samples and on a daily basis during the analysis, it will be demonstrated that the instruments meet the operating performance standards established in the applicable analytical methods. If an instrument does not meet the performance standards it will be tuned, repaired, or replaced until the performance criteria are achieved.

7.1.2 Calibration Curve

For analyses of analytes listed in Section 8 of this QAPP, instruments will be calibrated or standardized, as appropriate for the analytical method being used, prior to the analysis of each batch of samples. Instrument calibration will be verified on the frequency as prescribed in the applicable protocols (*e.g.*, every 12 hours for volatile and semivolatile organic compounds). A new calibration curve will be established if the response observed in the analysis of the continuing calibration check standard varies outside of prescribed protocol limits. The details to the calibration procedures are described in the analytical methods and laboratory SOPs.

7.2 Field Calibration

In addition to the laboratory analyses conducted during the course of this investigation, field measurements of pH, specific conductance, temperature, dissolved oxygen, Eh, and turbidity will be taken for ground water samples. The following is a brief discussion on field instrument calibration.

Instruments and equipment used to gather, generate, or measure environmental data will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications.

Equipment to be used during the field sampling will be examined to confirm that it is in good operating condition. This includes checking the manufacturer's operating manual and the instructions for each instrument to ensure that maintenance requirements are being observed. Field notes from previous sampling trips will be reviewed so notations on prior equipment problems are not overlooked, and those necessary repairs to equipment have been completed. A spare pH electrode and a thermometer will be sent to sampling locations where pH and temperature measurements are required, including those locations where a specific conductivity probe/thermometer is required.

Field instruments will include a water level indicator and a multi-function flow through cell and meter such as the QED MP-20 that has multiple sondes for specific conductivity, DO, pH, Eh, Temperature and turbidity. In the event that an internally calibrated field instrument fails to meet calibration/checkout procedures, it will be removed from service.

The equipment will be checked for any mechanical or electrical failures, weak batteries, and cracked or fouled electrodes before mobilizing for field activities. Calibrations and repairs will be recorded in a bound notebook with the date and the name of the person making repairs/calibrations. The equipment will be calibrated before use and at least once for every half day of use. In the event that a multiple sonde meter is not available, single sonde meters such as those listed below will be used for field measurements.

7.2.1 pH

The pH measurements will be made using a Geotech Model P3 flow-through cell (or equivalent). During use, the pH probe will be calibrated utilizing pH 4 and pH 7 buffer solutions. The pH of each sample will be measured in the flow-through cell. The pH measurements will be recorded to the nearest 0.1 pH unit.

7.2.2 Specific Conductance

The specific conductance probe will be calibrated to a stock calibration solution. The calibration must be within 10 percent of the calibration value of the solution. Specific conductance measurements will be made in the flow-through cell, and are automatically corrected by the instrument to 25°C. Measurements will be reported in $\mu\text{mhos/cm}$.

7.2.3 Temperature

Temperature will be measured to the nearest 0.1°C within the flow-through cell. Temperature measurements are utilized directly by the instrument to correct the specific conductance reading.

7.2.4 Turbidity

To assess monitoring well development and the representative nature of groundwater samples, the groundwater will be field-analyzed for turbidity using an in-field nephelometer (Hach Model 2100P, or equivalent). The meter will be calibrated before use according to procedures outlined in the operations manual.

7.2.5 Dissolved Oxygen

The DO measurements will be made using an YSI Model 95 or Geotech Model P3 Dissolved Oxygen Meter (or equivalent). Calibration consists of exposing the probe to a known oxygen concentration such as air at 100 percent relative humidity or water of a known oxygen content, and then adjusting the O₂ CALIB control so the display shows a reading that matches the O₂ concentration of the known sample. The instrument is automatically temperature compensated to an accuracy of ± 1 percent of the dissolved oxygen reading between 5° and 45°C; and to an accuracy of ± 1.5 - 2 percent between 0° and 5°C.

Section 8

Analytical Procedures

8.1 Laboratory Analysis

The laboratory will follow analytical procedures detailed in USEPA-approved methods and laboratory SOPs. Samples will be analyzed for the site-specific constituents of interest as listed in Table 3 of this QAPP.

Analytical parameters used to assess natural attenuation and to engineer the remedial design include ammonia, nitrate, phosphorus, sulfate, methane, heterotrophic bacteria plate count, TSS, and TDS. Analytical methods to be used for these analytes are listed below:

- Ammonia-N – USEPA Method 350.3;
- Nitrate-N – USEPA Method 353.2;
- Phosphorus – USEPA Method 365.2;
- Dissolved Lead – Method 6010B (SW-846);
- Sulfate – USEPA Method 375.4 or 300.0;
- Methane – Method 3810 (SW-846);
- Heterotrophic bacteria plate count – Method 9215B (SW-846);
- TSS – USEPA Method 160.2;
- TDS – USEPA Method 160.1

The reporting limits for the analyses are listed in Table 4.

Table 3
Natural Attenuation and Remedial Design Analytical Methods

FIELD PARAMETERS	METHOD/EQUIPMENT	FREQUENCY
Dissolved oxygen	360.1 ⁽²⁾ /Probe/Hach Kit	Quarterly
Redox potential (Eh)	⁽⁴⁾ Redox electrode	Quarterly
pH	150.1 ⁽²⁾ /pH electrode	Quarterly
Temperature	From conductivity probe	Quarterly
Turbidity	Turbidimeter	Quarterly
Specific conductance	120.1 ⁽²⁾ /Electrical conductivity meter	Quarterly
Ferrous iron	Hach Kit; Method 8146	Quarterly
Carbon Dioxide (CO ₂)	Hach kit	Quarterly
Alkalinity (total)	Hach kit	Quarterly
Depth to water ⁽⁵⁾	Electric tape/Water Level Indicator	Quarterly
LABORATORY PARAMETERS	METHOD	FREQUENCY
Benzene	602 ⁽¹⁾	Quarterly
Toluene	602 ⁽¹⁾	Quarterly
Ethylbenzene	602 ⁽¹⁾	Quarterly
Xylenes	602 ⁽¹⁾	Quarterly
DEHP	625 ⁽¹⁾	Quarterly
Ammonia Nitrogen (N)	350.3 ⁽²⁾	Quarterly
Nitrate Nitrogen (N)	353.2 ⁽²⁾ or 4110B ⁽²⁾⁽⁴⁾	Quarterly
Sulfate	375.4 ⁽²⁾ or 4110B ⁽²⁾⁽⁴⁾	Quarterly
Heterotrophic Plate Count	9215B ⁽⁴⁾	Quarterly
Methane	3810 ⁽³⁾	Quarterly
Phosphorus	365.2 ⁽²⁾	Quarterly
Dissolved Lead	6010B ⁽³⁾	Quarterly
Total Dissolved Solids (TDS)	160.1 ⁽¹⁾	Quarterly
Total Suspended Solids (TSS)	160.2 ⁽¹⁾	Quarterly

Notes:

- (1) Federal Register 40 CFR Part 136, Vol. 49, No. 209, Test Parameters for the Analysis of Pollutants.
- (2) USEPA 300/4-79-020 Methods for Chemical Analysis of Water and Waste.
- (3) SW-846, Test Methods for Evaluating Solid Waste, Physical and Chemical Methods, U.S. EPA, 3rd Edition, 1986.
- (4) Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998.
- (5) All wells listed on Table 1 will be measured before sampling begins.

Table 4
Natural Attenuation and Remedial Design Analytical Reporting Limits

Analyte	Reporting Limit
Ammonia nitrogen	0.10 mg/L
Nitrate nitrogen	0.1 mg/L
Phosphorus	0.03 mg/L
Dissolved Lead	0.0084 mg/L
Sulfate	5 mg/L
Methane	5 µg/L
Benzene	0.25 µg/L
Toluene	0.25 µg/L
Ethylbenzene	0.25 µg/L
Xylenes (total)	0.25 µg/L
DEHP	0.5 µg/L
Total Suspended Solids (TSS)	10 mg/L
Total Dissolved Solids (TDS)	20 mg/L
Heterotrophic Plate Count	1 cfu/mL

NOTES:

cfu/mL: Colony forming units/milliliter

mg/L: Milligrams per liter

µg/L: Micrograms per liter

8.2 Field Analyses

To ensure that the analytical data gathered in the field are both valid and unbiased, the following steps will be taken:

- Field samplers will be trained in the use of each piece of equipment.
- Operating manuals will accompany each piece of equipment in the field.
- Preventive maintenance programs will be carried out on a scheduled basis.
- Spare components will be taken into the field in case of equipment failure or damage.
- Instruments will be calibrated on a daily basis and rechecked as specified in the SOPs.
- Readings and calibrations will be documented.

The accuracy, sensitivity, and precision of the field analytical techniques for measuring water levels, temperature, specific conductivity, turbidity, DO, redox potential (Eh), and pH are dependent upon the specifications for the instruments used, as well as on the QC techniques employed during their use. Field analytical procedures to be used for this project are described in the attached SOPs and manufacturers O&M Manuals.

Section 9

Data Reporting, Validation, and Reduction

9.1 Field Data

Data validation practices will be followed to assure that raw data are not altered and that an audit trail is developed for data that require reduction. Field data, such as those generated during field measurements, will be entered directly into a bound field notebook. Only direct-reading instrumentation will be employed in the field. With the exception of the temperature correction for specific conductance, no calculation will be involved in field data reduction. Procedures to evaluate field data will primarily include checking for transcription errors and reviewing field notebooks, by field staff. This task is the responsibility of the Field Coordinator. The Field Coordinator will review field measurements recorded in the field books and field chain-of-custody forms to determine that procedures specified in the Monitoring Plan have been followed. Project team members will be responsible for proofing data transfers.

9.2 Laboratory Data

Lancaster Laboratory, Lancaster, Pennsylvania will perform in-house analytical data reduction under the direction of the Laboratory QA Manager. The Laboratory QA Manager will be responsible for assessing data quality and advising of any data that were rated "preliminary" or "unacceptable" or of other notations that would caution the data user of possible unreliability. Data reduction procedures for the analytical methods are included in the associated laboratory SOPs.

The analytical laboratories will prepare and retain full analytical and QC documentation. Such retained documentation need not be hard (paper) copy, but may be in other storage media (*e.g.*, computer diskette or magnetic tape). As needed, the laboratory will supply a hard copy of the retained information.

For analytical results generated using GC/MS (BETX and DEHP), the laboratory will provide full data packages. The electronic data deliverable will be in the format specified by RMT so that the data can be readily incorporated into a relational database.

For the indicator parameters (*i.e.*, ammonia, nitrate, phosphorus, dissolved lead, sulfate, methane, TSS, and TDS) used for natural attenuation assessments, the laboratories will provide the following information in each analytical data package submitted:

1. Cover sheet listing the samples included in the report and narrative comments describing problems encountered in analysis.
2. Tabulated analytical results.
3. Summaries of applicable QC sample analysis (spikes, duplicates, laboratory control samples and blanks).

Analytical Data Reports will be available from the laboratory within four weeks following the receipt of the samples.

Upon receipt of the laboratory data reports, the RMT Laboratory QA/QC Coordinator or designated data reviewer will validate the data. Data validation consists of a review of the data for compliance with the established QC criteria based on the spike, duplicate, and blank results provided by the laboratory. Data validation will determine whether the procedures specified in the QAPP were implemented, the DQOs specified in this QAPP were attained, the specified reporting limits were achieved, and the sample holding times were met. The GC/MS instrument performance check sample results will be evaluated. An evaluation of data accuracy, precision, sensitivity, and completeness, based on method-specific criteria, will be performed according to the following guidance documents:

- National Functional Guidelines for Inorganic Data Review. USEPA, February 1994.
- National Functional Guidelines for Organic Data Review. USEPA, October 1999.

Method specifications provided in the laboratory SOPs will be used as guidance for validating data for non-CLP analytes listed in this QAPP.

- The data validation report will address the following items:
 - Overall quality and usability of the data
 - Evaluation of QC data, including precision, accuracy, and completeness of the data
 - Potential sample contamination due to blank contributions
 - Assessment of laboratory and field records
 - Actions regarding specific QC criteria exceedences.

RMT anticipates that data reporting for this phase of the investigation will consist of tabulating analytical results from Analytical Data Reports into summary tables through the use of computerized relational database and spreadsheet software. Reduced data will be placed in the central file maintained by the RMT Technical Coordinator.

9.3 Data Archival

The records management program will track investigation documentation so that it is available when the remedial design has been completed. Accountable documentation include items such as logbooks, field data records, correspondence, Chain-of-Custody records, analytical reports, photographs, computer disks, and final reports. The RMT Technical Coordinator is responsible for maintaining a file in which all accountable documents will be inventoried. Raw data generated during field operations will be filed to eliminate or correct errors arising from the transfer of data. In order to avoid errors in the transfer of data, copies of raw data from the field notebooks and the data as received from the laboratory will be entered into a data file. The data file will serve as the ultimate archive for information and data generated during this Post-Remedial monitoring.

Section 10

Internal Quality Control Checks

Quality Control procedures for field analyses such as pH, specific conductivity, dissolved oxygen, Eh, turbidity, and temperature measurements consist of proper instrument calibration.

Internal Quality Control Checks used to assess field sampling precision and bias include the collection of the following blanks and samples:

- **Atmospheric Blanks** - These blanks consist of organic free, deionized water contained in each sample container with any preservatives required for that analysis. These will serve as a QC check on the field sampling methods for the analytes, container cleanliness, and external contamination. An atmospheric blank will be submitted for each sampling event.
- **Trip Blanks** - These blanks consists of organic free, deionized water contained in volatile organic compound (VOC) sample containers and preserved similar to VOC samples. These samples serve as a QC check on potential external contamination and/or cross-contamination between VOC samples during shipping and storage. A trip blank will accompany each cooler of VOC samples sent to the laboratory.
- **Rinsate Blanks** - These are samples of organic free, deionized water, which have been in contact with decontaminated sampling, and/or drilling equipment. These samples serve as a QC check on the decontamination procedure. One Rinsate Blank will be collected for every twenty field samples collected only when non-dedicated equipment is used. The rinsate blank should be collected after pouring analyte-free water over/through appropriate sampling equipment (*e.g.*, bailers, tubing, and pumps).
- **Field Duplicate Samples** - Duplicate samples will be collected to allow determination of analytical repeatability and sample homogeneity. At a minimum, one duplicate sample for every twenty ground and/or surface water samples, and one duplicate for every twenty soil and/or sediment samples, will be collected and submitted for analysis. Duplicate samples will be labeled in a manner such that their sampling point location is not disclosed to the laboratory. The duplicate sample number (*e.g.* DU-1) and its corresponding sample location will be recorded in the field notebook. Sampling date and time will *not* be filled out on the label of the duplicate sample nor on the Chain-of-Custody form in order to not to disclose the duplicate's sample point location.
- **Matrix Spike/Matrix Spike Duplicate Samples** – The laboratory will analyze a matrix spike/matrix spike duplicate (MS/MSD, organic compounds) and sample spike/sample duplicate (inorganic analytes) sample pairs for as QC checks for accuracy and precision.

MS/MSD sample pairs are actually laboratory analytical QC items, which are discussed here because sufficient sample must be collected in the field if these analyses are performed using the samples from the L.E. Carpenter site. Sufficient volume for one MS/MSD sample pair will be collected for every 20 groundwater samples. These samples will allow the amount of recovery of spike constituents to be determined for matrix effects specific to the study site, through the addition of known concentrations of compounds into the sample at the laboratory and then performing the analysis. The spike concentrations added into QC samples will be consistent with the analytical methods and laboratory SOPs.

Section 11

Performance and System Audits

11.1 Field Performance Audits

11.1.1 Internal Field Audits

On-site audits may be performed to review field-related Quality Assurance activities. The Field Coordinator, the Technical Coordinator, or a senior technical scientist may conduct internal audits.

Specific elements of the on-site audit may include, but are not limited to, verification of the following items:

- Completeness and accuracy of sample Chain-of-Custody forms, including documentation of times, dates, transaction descriptions and signatures;
- Completeness and accuracy of sample identification labels, including notation of time, date, location, type of sample, person(s) collecting sample, preservation method used, and type of testing required;
- Completeness and accuracy of field notebooks, including documentation of times, dates, drillers' names, sampling method used, sampling locations, number of samples taken, name of person(s) collecting samples, types of samples, results of field measurements, soil logs and problems encountered during sampling;
- Adherence to health and safety guidelines including wearing of proper protective clothing. Level D protective clothing will be worn at a minimum and will be upgraded, if necessary, as specified in the Health and Safety Plan;
- Adherence to decontamination procedures as outlined in the site Health and Safety Plan, including proper washing or steam cleaning of pumps and pump tubing, bailers, and soil sampling equipment;
- Proper calibration and maintenance of field instruments;
- Adherence to sample collection, preparation, preservation, and storage procedures as outlined in the Monitoring Plan.

11.1.2 External Field Audits

The USEPA Region II and/or the NJDEP may conduct external field audits.

11.2 Laboratory Performance and System Audits

11.2.1 Internal Laboratory Audits

Laboratory audits consist of random data reviews, continuous trend analysis of laboratory QA data, and periodic analysis of performance evaluation samples. Systems audits are performed to verify the continuity of personnel, instrumentation, and quality control requirements contained in the SOPs. Each analytical laboratory is responsible for its own audits.

11.2.2 External Laboratory Audits

USEPA Region II and/or the NJDEP may conduct external laboratory system audits.

Section 12

Preventative Maintenance

The maintenance procedures discussed in the following subsections will be performed to maximize efficiency and minimize downtime in the laboratory and while working on the L.E. Carpenter Site.

12.1 Laboratory Maintenance

As part of their QA/QC program, the analytical laboratory to minimize the occurrence of instrument failure and other system malfunctions conducts a routine preventive maintenance program. Each team in the laboratory performs routine scheduled maintenance and repair or coordinate with the vendor for the repair of all instruments. All laboratory instruments are maintained in accordance with manufacturer's specifications or as appropriate for the instrument. The preventive maintenance procedures for the test instruments will follow established by the laboratory's SOPs. All maintenance activities will be documented in the record books to provide a history of maintenance records.

12.2 Field Maintenance

Routine daily maintenance procedures conducted in the field will include the following:

- Removal of surface dirt and debris from exposed surfaces of the sampling equipment measurement systems.
- Storage of equipment away from the elements.
- Daily inspections of sampling equipment and measurement systems for possible problems (*e.g.*, cracked or clogged lines or tubing; weak batteries).

Spare and replacement parts stored in the field to minimize downtime include the following:

- Appropriately sized batteries
- Extra precleaned sample bottles
- Locks
- Calibration solutions for each meter

Backup instruments and equipment should be available on-site or within 1 day via shipment to avoid delays in the field schedule.

Section 13

Specific Routine Procedures Used to Assess Data Precision Accuracy and Completeness

13.1 Laboratory Data Quality Assessment

The RMT Laboratory Coordinator and QA/QC Coordinator will oversee data validation.

The quality of the laboratory data will be assessed by the Laboratory Coordinator using CLP protocol-specific criteria, validation methods described in Section 9 of this QAPP. Data qualifiers described in the document, if applied to the data, may be added as lower case letters to distinguish them from upper case qualifiers added by the laboratory. The Laboratory Coordinator will check that data packages include a narrative to document variations from the analytical protocol and actions taken by the laboratory to address those variations. The Laboratory QA/QC Coordinator will advise the Project Team of data having questionable or unacceptable quality and procedural deviations noted in the laboratory report narrative.

13.2 Field Data Quality Assessment

To assist in collecting field data accurately and correctly, the Field Coordinator will issue specific instructions to personnel involved in field data acquisition. At the end of each field event the Field Coordinator will review the field books used by project personnel to check that tasks were performed as specified in the instructions. Field books will be reviewed periodically throughout the entire project.

Raw data and reduced data will be submitted by project personnel to the RMT Technical Coordinator for review. Equations, calculations, data transfers, consistent units, and significant figures will be subject to this Quality Assurance review.

Section 14

Corrective Action

Corrective actions may be required for two classes of problems: 1) analytical and equipment problems and 2) nonconformance problems. Analytical and equipment problems may occur during sampling and sample handling, sample preparation, laboratory instrumental analysis, and data review.

If a nonconformance with the established quality control procedures in this QAPP is identified, it will be noted in the logbooks, and corrected in accordance with the QAPP. For noncompliance problems, a corrective action program will be determined and implemented at the time the problem is identified and reported. The person who identifies the problem is responsible for notifying the appropriate field or laboratory personnel. The laboratories will communicate analytical problems to the RMT Technical Coordinator or the RMT Laboratory QA/QC Coordinator. Implementation of corrective action will be confirmed in writing through the same personnel. Field corrective actions will be reported to the RMT Technical Coordinator, implemented, and documented in the field logbook. The RMT Technical Coordinator will report any corrective action that directly impacts project data quality objectives to the USEPA Region II and NJDEP Project Managers.

14.1 Field Measurement Corrective Action

Technical staff and project personnel will be responsible for reporting technical or QA nonconformance or suspected deficiencies of an activity or issued document by reporting the situation to the RMT Field Coordinator or designee. If it is determined that the situation has impacted the quality of the data, a nonconformance report will be completed by the RMT Field Coordinator and distributed to the appropriate personnel. The field staff, in conjunction with the RMT Field Coordinator, will recommend a corrective action. The RMT Field Coordinator will be responsible for ensuring that corrective action for nonconformance has been implemented. The RMT Field Coordinator will be responsible for the following:

- Evaluating all reported nonconformance
- Controlling additional work on nonconforming items
- Determining future action to be taken
- Noting nonconformance in the field logbook
- Reviewing nonconformance reports and corrective actions taken

- Ensuring that nonconformance reports are included in the final project files

If appropriate, the RMT Field Coordinator will ensure that no additional work that is dependent on the nonconforming activity is performed until the corrective actions are completed.

14.2 Laboratory Corrective Action

Corrective actions are required whenever an out-of-control event or potential out-of-control event is noted. The investigative action taken is somewhat dependent on the analysis and the event. Corrective action in the laboratory may occur prior to, during, and after the initial analysis.

A number of conditions, such as broken sample containers, multiple sample phases, low/high pH readings, or potentially high-concentration samples may be identified during sample login or just prior to analysis. The corrective action program is under the supervision of the Lancaster Laboratory QA Manager. Following a consultation with laboratory scientists and technicians and team leaders, it may be necessary for the Lancaster Laboratory QA Manager to approve the implementation of corrective action. Some conditions during or after analysis may automatically trigger corrective action or optional procedures. These conditions may include dilution of samples, additional sample extract cleanup, automatic reinjection/reanalysis when certain quality control criteria are not met, etc. Corrective actions may be necessary if any of the following occur:

- QC data are outside the warning or acceptable windows for precision and accuracy.
- Blanks contain target analytes above acceptable levels.
- Undesirable trends are detected in spike recoveries or the RPD between duplicates.
- There are unusual changes in detection limits.
- Deficiencies are detected by the Laboratory during internal or external audits or from the results of performance evaluation samples.
- Inquiries concerning data quality are received.

Corrective action procedures are often handled at the bench level by the analyst, who reviews the preparation or extraction procedure that was used for possible errors, and checks the instrument calibration, spike, and calibration mixes, and the instrument sensitivity. If the problem persists or cannot be identified, the matter may be referred to the laboratory team leader, and/or the Laboratory QA Officer for further investigation. Documentation of the corrective action procedure, whether resolved or not, is placed in the Laboratories project file. The laboratory will provide documentation as to what, if any, corrective actions were initiated

Section 15

Quality Assurance Documentation to USEPA

The RMT Technical Coordinator, in conjunction with the Field Coordinator and Laboratory QA/QC Coordinator, will submit a project status report each month. This report may include the following types of information relating to Quality Assurance Activities:

- Significant irregularities noted in the field notebook during the sampling procedure.
- Results of performance and system audits, if conducted.

QA/QC data generated by the laboratory and a case narrative will be included in the CLP data packages.

Pertinent quality assurance documentation will be submitted to the following person at USEPA and NJDEP:

Addressees:

Mr. Anthony Cinque
Case Manager
NJDEP
Bureau of Federal Case Management
Division of Responsible Site Party Remediation
CN028
Trenton, New Jersey 08625-0028
(609) 633-7261 phone
(609) 633-1439 fax
gzervas@dep.state.nj.us

Mr. Stephen Cipot
Project Manager
USEPA Region II
290 Broadway, Floor 19
New York, NY 10007-1866
(212) 637-4411 phone
(212) 637-4429 fax
cipot.stephen@epamail.epa.gov

Section 16

References

- American Public Health Association. 1995. Standard methods for the examination of water and wastes.
- USEPA. 1979. Methods for chemical analysis of water and wastes. USEPA Office of Research and Development. EPA-600/4-79-020, including 1982 and 1984 versions.
- USEPA. 1986. NEIC Policies and Procedures Manual. EPA 330/978-001-R
- USEPA. 1987. A compendium of Superfund field operations methods. USEPA, Office of Emergency and Remedial Response, EPA/540/P-87/001.
- USEPA. 1993. Data Quality Objectives Process for Superfund, Interim Final Guidance, OSWER Directive 9355.9-01. EPA 540/R-93/071. September 1993.
- USEPA. 1994. National Functional Guidelines for Inorganic Data Review. EPA-540/R-94-013, February 1994.
- USEPA, Region 4. 1996. Environmental investigations standard operating procedures and quality assurance manual. USEPA Region 4 Science and Ecosystem Division, May 1996.
- USEPA. 1997a. EPA requirements for quality assurance project plans for environmental data operations. Document No. EPA QA/R-5, October 1997.
- USEPA. 1999. National Functional Guidelines for Organic Data Review. EPA-540/R-99-008, October 1999.

Attachment 1

Low-Flow Sampling Methods

Introduction

This appendix summarizes methods that will be used to collect representative groundwater samples for chemical analysis. Equipment and techniques that will be followed to purge and to obtain samples are discussed in detail. This section includes excerpts from the Wisconsin Department of Natural Resources Groundwater Sampling Desk Reference, WDNR PUBL-DG-03796 (September 1996) that deal specifically with low-flow sampling methods.

Wells That Do NOT Purge Dry

This section applies to wells that take less than ~1 hour for the water level in the well to recover (or nearly so) after they have been purged.

The following purging and sampling procedures will be used for wells that do not purge dry. The first procedure listed consistently yields the *highest level of data quality*. The last procedure listed may yield a *lower level of data quality*:

- A. **Low-flow purging < 1 L/min (0.26 gpm), low-flow sampling < 300 ml/min (0.3 L/min or 0.1 gpm) and the monitoring of indicator parameters for stability in a closed flow-through cell.** To obtain the highest-quality, most representative, and consistent groundwater quality measurements and analytical data, purge the well at an average rate of 1 liter/minute (L/min) or less, sample at an average rate of 300 ml/min (0.3 L/min) or less and monitor indicator parameters in a closed flow-through cell until their stability is reached. This procedure will be enhanced by using a dedicated pumping system (left in the well "permanently").

Purging and sampling rates should be at or less than the natural flow conditions existing in the aquifer influenced by the well. Drawdown during purging should be minimal and the water level in the well should stabilize before the flow rate is decreased to 300 ml/min or less to commence sampling. While maintaining a sampling flow rate of 300 ml/min or less, the water level should be stable or preferably recovering as samples are collected (this ensures that any remaining stagnant water above the pump is not incorporated into the water collected for samples).

Do not reduce a pump's flow rate by using valves. The resulting pressure drop across the valve (also known as an "orifice effect") can alter sensitive samples, usually by degassing.

Purge the well until at least three consecutive readings, spaced ~2 minutes or ~0.5 well volumes or more apart, are within the following indicator parameter ranges:

Dissolved Oxygen	±0.2 mg/L
Specific Conductance	±5.0 µmhos/cm for values < 1000 µmhos/cm ±10.0 µmhos/cm for values > 1000 µmhos/cm
pH	±0.1 pH units
Temperature	0.1°C
Turbidity	< 5 NTUs (Required if metals samples will not be filtered. Recommended if sorptive compounds or elements are collected. Optional , but recommended if other compounds or elements are collected)
Eh (optional)	±30 mv

Stable dissolved oxygen, specific conductance and turbidity readings are considered the most reliable parameters for indicating that stagnant water has been replaced by formation water. You may adjust the ± ranges and indicator parameters used to indicate replacement to reflect site-specific data, geochemistry, and hydrogeologic conditions.

Turbidity stabilization and NTU readings below 5 are required if metals samples will not be filtered. Low turbidity readings (*i.e.*, < 5 NTUs), when measured using low-flowing pumping techniques, should represent colloids and particulates naturally mobile in groundwater under natural flow conditions. Turbidity stabilization should also be monitored when collecting sorptive, hydrophobic, or high octanol-water partition coefficient (K_{ow}) compounds or elements.

Or: Purge the well until the readings for each indicator parameter listed above vary within ± 10 percent, over three or more consecutive readings spaced ~2 minutes or ~0.5 well volumes or more apart.

Collect samples from the pump's discharge line before the water enters the flow-through cell. Air pockets in the flow-through cell and probes inserted into the flow-through cell can degrade sample water quality. Either disconnect the sample tubing from the flow-through cell before collecting samples or connect a "tee" junction with an on/off sampling valve between the well and the flow-through cell to collect samples.

Low-flow purging/sampling may not be necessary or may be impractical under the following circumstances:

- Well purges dry before indicator parameters stabilize.
 - Parameters are not affected by aeration, agitation, or the gain or loss of dissolved gasses (and subsequent change in sample pH, etc.).
 - Data quality objectives for a project do not require the level of rigor and stringency inherent in low-flow purging/sampling.
 - An alternative purging and sampling technique has been proven to meet the data quality objectives for the project.
 - Procedures are extremely burdensome and time consuming.
- B. **Purging FOUR well volumes and then sampling with a low-flow pump.** You may use this method when stabilization of the indicator parameters is not achieved in a reasonable amount of time (2 hours). As with the low-flow purging and sampling technique, the purging and sampling rate should still be kept low and should not exceed the natural flow conditions of the aquifer, if possible. The sampling flow rate should be less than the purging flow rate.

Wells That Purge Dry

This section applies to wells that take ~1 or more hours to recover (or nearly so) after they have been purged dry (or nearly so).

Ideally, sample and purge wells at flow rates at or less than the natural flow conditions in the aquifer influenced by the well. Drawdown and turbidity during purging and sampling should be minimal; however, for wells that recover slowly, attaining little drawdown and low turbidity may be nearly impossible. Slowly-recovering wells should still be purged and sampled with minimal disturbance to the water and fines in and around the well and to obtain samples with the lowest turbidity and oxygenation possible.

For slowly-recovering wells that purge dry, bail or pump the well dry, or nearly so, and allow it to recover at least once before collecting samples. If time permits, purge the well a second time. If recovery permits, collect samples from the well within 24 hours of the final purging.

If you are collecting sensitive samples such as VOCs and trace metals, the following procedure should yield samples with the highest data quality. Purge the well dry, or nearly so, using a very low purging rate (< 300 ml/min or 0.1 gpm). Allow the well to recover, or nearly so, at least once before collecting samples. If time permits, purge the well a second time and collect samples within 24 hours. Low-flow pumping should minimize the disturbance of fines in and

around the well during purging and sampling and should therefore minimize sample turbidity.

Sample Collection

During sampling, primary objectives and considerations include minimizing sample disturbance, avoiding sample exposure to air and extraneous contamination, and preserving sample integrity throughout collection.

Collect sample parameters in the following order:

1. Unfiltered samples for in-field water quality measurements (not necessary if down well or flow-through cell measurements are taken).
2. Volatile organic compounds (VOCs).
3. Non-filtered, non-preserved (*e.g.*, sulfate, chromium VI, mercury, semi- and non-volatiles, pesticides, PCBs).
4. Non-filtered, preserved (*e.g.*, nitrogen series [ammonia, nitrates, nitrites, etc.], phenolics, total phosphorous, total metals, cyanide, total organic carbon).
5. Filtered, preserved immediately (*e.g.*, dissolved metals).
6. Miscellaneous parameters.

Collect sulfate samples before sulfuric acid preserved samples (*e.g.*, nitrogen series). Collect nitrogen series samples before nitric acid preserved samples (*e.g.*, boron, dissolved metals). This will prevent accidental contamination of a sample with a preservative intended for another sample (*e.g.*, sulfuric acid preservation contaminating an unpreserved sulfate sample).

Before opening and filling sample containers, check the sampling area for potential sources of extraneous contamination. Make sure the area around the well is clean and that contaminated equipment is kept away from the well. Protect the samples from airborne contaminants such as engine exhaust, blowing dust and organic fumes (*e.g.*, gas cans); sample upwind of these contaminants or remove them before sampling. Choose gloves appropriate for the contaminants you encounter. Change into new, clean gloves every time you sample a new well or suspect your gloves have become contaminated. Do not attempt to decontaminate or reuse gloves; use disposables.

Do not open sample containers until it is time to fill them. Immediately after filling a sample container, if you haven't already done so, add any required preservative—filter first, if required—replace the cap, label the container and place the sample on ice in a cooler. Following these procedures will help minimize sample turbulence, agitation, volatilization,

degassing, atmospheric exposure, biodegradation, and exposure to extraneous contamination and heating of samples.

Attachment 2

Chain of Custody Form

Analysis Request/ Environmental Services Chain of Custody



For Lancaster Laboratories use only

Acct. # _____ Group# _____ Sample # _____

COC #

Please print. Instructions on reverse side correspond with circled numbers.

1 Client: _____ Acct. #: _____ Project Name/ #: _____ PWSID #: _____ Project Manager: _____ P.O. #: _____ Sampler: _____ Quote #: _____ Name of state where samples were collected: _____				Matrix Check if Potable <input type="checkbox"/> NPDES <input type="checkbox"/> Applicable <input type="checkbox"/> Soil _____ Water _____ Other _____			4 5 Analyses Requested <table style="width: 100%; text-align: center;"> <tr> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> <td>Type Here.....</td> </tr> </table>								Type Here.....	Type Here.....	Type Here.....	Type Here.....	Type Here.....	Type Here.....	Type Here.....	Type Here.....	Type Here.....	For Lab Use Only FSC: _____ SCR #: _____		6 Temperature of samples upon receipt (if requested)																																																																																																																																																																															
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8 Data Package Options (please circle if required) <table style="width: 100%;"> <tr> <td>QC Summary</td> <td>Type VI (Raw Data)</td> <td>SDG Complete? Yes No</td> </tr> <tr> <td>Type I (Tier I)</td> <td>GLP</td> <td>Site-specific QC required? Yes No</td> </tr> <tr> <td>Type II (Tier II)</td> <td>Other</td> <td>(If yes, indicate QC sample and submit triplicate volume.)</td> </tr> <tr> <td>Type III (NJ Red. Del.)</td> <td></td> <td>Internal Chain of Custody required? Yes No</td> </tr> <tr> <td>Type IV (CLP)</td> <td></td> <td></td> </tr> </table>				QC Summary	Type VI (Raw Data)	SDG Complete? Yes No	Type I (Tier I)	GLP	Site-specific QC required? Yes No	Type II (Tier II)	Other	(If yes, indicate QC sample and submit triplicate volume.)	Type III (NJ Red. Del.)		Internal Chain of Custody required? Yes No	Type IV (CLP)																																																																																																																																																																																									
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Attachment 3

Laboratory Bottle Label
